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ABSTRACT

This report gives an overview of the primary issues identified through case studies on exemplary training programs for integrated manufacturing. Following an introduction, Chapter 2 outlines the key elements of integrated manufacturing. Chapter 3 describes the context of integrated manufacturing with reference to Australian and worldwide trends: a major structural shift in employment to service industries; newer "high tech" industries; integrated manufacturing; sophistication of world markets; availability of computer technologies; and changes in work organization. Chapters 4 and 5 contain case studies of six manufacturers and seven educational institutions with exemplary training arrangements. Case studies of manufacturers describe the firm's problems before its involvement with integrated manufacturing, how it identified training needs, its competitive strategy, its present condition, training arrangement, and the future. Case studies of educational institutions describe the curricula offered, teaching approach, and links with industry. Chapter 6 outlines work force skills required for integrated manufacturing, including cross-disciplinary, cognitive, and communication skills. Chapter 7 discusses the training responses required, such as more intensive initial training, continuing education, new course content, joint ventures with industry, and good range of technical equipment. Appendixes include a 151-item bibliography, a glossary, a more detailed description of one educational institution, and examples of integrated manufacturing courses. (YLB)

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Geoff Hayton
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TRAINING FOR INTEGRATED MANUFACTURING : CASE STUDIES

GEOFF HAYTON
PHILIP LOVEDER

Adelaide

1990

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Abbreviations

ACADS	Australian Computer Aided Design Society
AGV	Automated Guided Vehicle
AMC	Australian Manufacturing Council
APICS	Advanced Production & Inventory Control Systems
ATEC	Advanced Technology Education Centre (Regency College, Adelaide)
ATG	Applied Technology Group (Singapore)
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CAP	Computer Aided Production
CDM	Centre for Design and Manufacturing (Pennsylvania, USA)
CIM	Computer Integrated Manufacturing
CIMM	Computer Integrated Manufacture and Management
CNC	Computer Numerical Control
CWQI	Company Wide Quality Improvement
DAA	Design for Automated Assembly
DFA	Design for Assembly
DITAC	Department of Industry, Technology and Commerce
EDB	Economic Development Board (Singapore)
EDI	Electronic Data Interchange
FMEA	Failure Mode and Effect Analysis
FMS	Flexible Manufacturing Systems
GSI	German Singapore Institute
IBM	International Business Machines
IES	Industry Extension Service (North Carolina, USA)
IMDP	Integrated Manufacturing Demonstration Program

IMSEI	Integrated Manufacturing Systems Engineering Institute (North Carolina, USA)
IPG	Industrial Project Group (Singapore)
JIT	Just-In-Time
LAN	Local Area Network
MPS	Master Production Schedule
MRP II	Manufacturing Resource Planning
MSE	Manufacturing Systems Engineering
NEC	Nippon Electronics Company
OPT	Optimised Production Technology
PEI	Precision Engineering Institute (Singapore)
PLC	Programmable Logic Control
PRCS	Philips Radio Communication Systems
SACFM	South Australian Centre for Manufacturing
SAIT	South Australian Institute of Technology
SAGASCO	South Australian Gas Company
TQC	Total Quality Control
TQM	Total Quality Management
VAM	Value-Added Management
VITB	Vocational Industrial Training Board (Singapore)

CHAPTER 1: INTRODUCTION

This study on training for integrated manufacturing was an in-house project of the TAFE National Centre for Research and Development. The project was begun in 1988 and finished in 1990, and was undertaken by Geoff Hayton, Mohammed Harun, and Philip Loveder. The project was guided by a Project Advisory Committee of representatives from industry, TAFE and government (see Appendix A).

The objectives of the project were:

- to describe the industry trends in integrated manufacturing in Australia and overseas;
- to identify Australia's broad training and retraining needs in integrated manufacturing by means of a review of recent relevant studies;
- to describe cases of exemplary training arrangements for integrated manufacturing in Australia and overseas, including manufacturing firms and educational institutions; and
- to make recommendations on the provision in Australia of training and retraining in integrated manufacturing.

The two major outcomes of the project were a review of the literature published in December, 1988 (Hayton & Harun 1988), and this report on the case studies, published in September, 1990.

The project involved two main stages as follows:

The first stage involved a review of the literature on-

- trends in integrated manufacturing in Australia and overseas;
- Australia's training and retraining needs in this area; and
- the current provision of training and retraining in Australia.

The second stage involved the conduct of case studies, using literature searches, interviews and observations, on exemplary training arrangements for integrated manufacturing. Six case studies of manufacturing firms and seven case studies of educational institutions were selected.

The case studies were selected after the review of the literature. The selection was based on the following criteria:

- case studies of up-to-date integrated manufacturing techniques (by world standards) was undertaken. These were sought in countries where integrated manufacturing technology was well advanced;
- the training arrangements were innovative, economical, and successful; and
- initial training to trade and para-professional level, and retraining, was covered.

Each case study describes the training arrangement, how it was set up and managed, the method of curriculum design and development used, and how it fitted the accreditation system. The case studies of individual firms include details of the firm's management approach, its work organisation, how the firm identified its training needs and what were the broad training needs of the firm's staff at all levels. The case studies of educational institutions also include details of how the institution identified vocational training needs.

Integrated manufacturing is important in Australia's manufacturing industries simply because it is becoming the main strategy whereby medium to large volume manufacturers attain international competitiveness. It is also important in vocational education and TAFE in particular, because training and retraining for integrated manufacturing requires significant changes to a wide range of existing courses, and the introduction of new courses. The success of integrated manufacturing is largely based on the skills held by our workforce.

Integrated manufacturing encompasses a wide variety of technical and sociological disciplines and issues. This report aims to give an overview of the main issues, with a focus on training implications for industry and for TAFE. This report will:

- outline the key elements of integrated manufacturing (Chapter 2);
- describe the context of integrated manufacturing with reference to Australian and world-wide trends (Chapter 3);
- describe case studies of manufacturers and educational institutions (Chapters 4 and 5);
- outline the workforce skills required for integrated manufacturing (Chapter 6); and
- discuss the training responses required (Chapter 7).

It is suggested that those with an interest in the training implications for TAFE or higher education read Chapters 1,2,3,5,6 and 7, reading only one or two case studies from Chapter 4. Those with an interest in the training implications for industry could read Chapters 1,2,3,4 and 6, reading only one or two case studies from Chapter 5. A brief guide to the case studies is presented at the beginning of Chapters 4 and 5.

The literature review published as part of this project describes a number of terms used for the concept of integrated manufacturing, or particular aspects of it.

Such terms include:

- flexible manufacturing;
- computer integrated manufacturing (CIM): and
- advanced manufacturing technology (AMT).

Our definition of integrated manufacturing encompasses the new approach to manufacturing in which both technical and human aspects of integration are crucial. It states:

> *Integrated manufacturing is a broad term describing a management approach which aims at simultaneously achieving efficiency, quality and flexibility by integrating all aspects of a manufacturing organisation's operation. It involves the integration of:*
>
> - *machines;*
> - *people;*
> - *people and machines; and*
> - *systems and procedures,*
>
> *by the application of information technologies and integrated types of work organisation.*

The term *information technologies* is used here in the broad sense to include computer and communication technologies (Hall et al. 1985, p.25-27).

The following chapter describes the key elements of integrated manufacturing, with illustrations from the case studies.

CHAPTER 2: UNDERSTANDING INTEGRATED MANUFACTURING

Most of the large manufacturing companies of today were once very small businesses. Those who began a business knew every aspect of it and everything that was happening at any given time. But as these businesses grew, individuals could no longer cope with all the skills involved, nor could they keep track of everything that was happening. It seemed natural to divide tasks and allocate them to those with specialist skills (Mortimer 1985, p.29).

It became clear that greater efficiency could be achieved by:

- greater specialisation of labour (because people can more easily learn a smaller range of tasks and perform them more efficiently); and
- mechanisation of specialised manufacturing operations (because machines could perform simple tasks faster and more consistently).

Thus, as manufacturing businesses grew, labour became more specialised, more manual operations were mechanised, and areas of specialisation became departments within the larger organisation.

However, greater specialisation has a price. More complex systems for moving materials and information are required, resulting in greater administrative overheads. Modern management techniques were devised to manage this complexity rather than eliminate it. Today, most manufacturing companies in Western countries have overheads in excess of 200% of direct production costs (Mortimer 1985, p.30; Brodner 1987, p.33).

Integrated manufacturing provides a very effective alternative but it requires a radically different way of thinking. Integrated manufacturing is a new manufacturing philosophy, not just a new technology like computer integrated manufacturing (CIM). The philosophy involves reducing complexity and bringing the whole manufacturing operation, not just production, into a single, well-coordinated whole unit. CIM technology however may be introduced in the later stages of implementation of an integrated manufacturing strategy. It is a powerful technology and potentially a key part of integrated manufacturing, but it must be seen as only an element of any comprehensive integrated manufacturing strategy.

Effective integrated manufacturing strategies will vary from company to company. However, companies adopting an integrated manufacturing strategy will usually undertake the same three steps:

- simplify;
- integrate;
- apply CIM technology as appropriate.

(Mortimer 1985, p.30).

Each of these steps will now be discussed. Appropriate examples from the case studies in Chapter 4 will be used to illustrate the role of each step in the overall integrated manufacturing process.

A company's competitiveness relies on its marketing, financial and manufacturing strategies. Many manufacturers in Western countries in the past have under-valued the contribution of manufacturing strategy to their overall competitiveness (Hayes & Wheelright 1984; Samson 1990, p.19-20; Hayton 1990, p.23-28).

SIMPLIFICATION OF MANUFACTURING

Simplifying a manufacturing organisation has a number of direct and indirect benefits (Bolwijn et al. 1986, p.145). The typical manufacturing operation of today is surprisingly complex. Complexity is evidenced in the flow of materials and products from goods inwards to despatch, and in the flow of information within information centres such as:

- management;
- marketing and sales;
- product design;
- engineering;
- purchasing;
- production/assembly;
- quality management;
- distribution.

Two examples of simplification or the reduction in complexity are discussed: Sigma Air-Conditioning and the Bridges Corporation, two of the case studies described in Chapter 4.

Sigma introduced MRP-II inventory and production planning and control into its operations with the intention of developing a single, easily accessible data system that could link all facets of the manufacturing process from initial tender information, through to production and despatch. The effect has been greatly improved interpersonal communication between the various groups within the company.

Sigma's integrated manufacturing approach was based on the principles of Advanced Production and Inventory Control Systems (APICS) and CAD, CAM, CNC and MRP-II. This has resulted in the simplification of both materials and product lead times which has meant a 30% reduction in actual lead times for new products.

Bridges Corporation followed a similar process of simplification to Sigma which involved the establishment of an integrated information system, and development of CAD/CAM and CIM capabilities in conjunction with MRP-II. The latter was considered important even though the benefits were not at the outset, entirely obvious. The company believed that an overall reduction in lead times of between 50% and 60% was possible in the near future, plus vastly improved inventory management and new product specification procedures.

The two companies have obviously benefitted from the reduction in complexity that has taken place. Previously, both companies exhibited considerable complexity in the flow of materials and product lead times resulting in large amounts of capital being tied up in stocks of raw materials, work in progress and finished products. Only a small amount of time was spent on production or assembly, most time being lost in 'waiting'. The various techniques employed (especially MRP-II, Just-in-Time, CAD/CAM/CNC/CIM) has given these companies a competitive edge.

Complexity in the flow of information on the other hand, leads to large amounts of paper waiting on desks for attention. This in turn leads to reduced efficiency and lower quality due to the inevitable delays in information transfer. In a complex system of material and product flow and information flow, any unplanned event - delays, market changes, machine breakdowns and labour disputes - can be disastrous.

Various methods of analysis may be used to help plan for simplification of manufacturing. The aim should be to undertake all tasks in the simplest and most timely way with simple and efficient information flow.

INTEGRATION OF MANUFACTURING

Integration should involve all aspects of manufacturing, not just production. Thus marketing, sales, purchasing, product design, production and distribution should be integrated by means of simple, timely and efficient flows of information and materials. The main components of integration as discussed in Chapter 1 are:

- machines;
- people;
- people and machines;
- systems and procedures.

The development of information technologies has greatly broadened the scope for integration of machines within manufacturing and may involve one or more of the following forms:

- the linking of two or more dedicated machines which deal with material flow and/or information flow;
- the consolidation of two or more operations in a programmable machine or robot;
- the linking of two or more functions such as design and production.

The integration of people may involve one or more of the following:

- a flat management structure with few hierarchical levels;
- the consolidation of departments;
- the formation of multi-task teams.

Integration through new approaches to work organisation is discussed in Chapter 3.

The integration of people and machines may involve improving the effectiveness of the person-machine interface, usually through computer technology, so the person has more control over the machine. This usually results in the operator and machine working more efficiently and more flexibly, and increases the level of responsibility that should be given to the operator.

The integration of systems and procedures through standard approaches such as:

- Manufacturing Resources Planning (MRP-II);
- Just-in-time scheduling (JIT);
- Total Quality Management (TQM),

can be introduced or modified to realise corporate goals. Integration involves ensuring that standards and protocols are common to all systems and procedures introduced.

Integration was an important factor in the manufacturing strategy of all the companies appearing in the case studies (see Chapter 4).

Sigma's strategy for integration is being achieved by establishing cross-functional teams (especially at the design and prototype manufacturing stages) and through the linking of CNC machine tools with the new computerised system.

Similarly, Bridges have integrated their information system to allow information flow between the design, manufacturing, marketing and business functions of the company. Investments in MRP-II, JIT and Flexible Manufacturing Systems (FMS) have also been a factor in the company's integrative activities.

Milford Fabricating Company (Detroit) has incorporated aspects of quality management and the linking of dedicated machines in respect to both information and materials flow as part of their integrated manufacturing strategy.

Philips (Cambridge) has implemented a computerised production control system and has partly integrated personnel functions by developing a flat management structure with few hierarchical levels. Effectively, only three main levels exist, which include a number of off-line specialised service departments and three large production centres (called 'technical centres'), each having their own technical support. Considering the size of the plant (approximately 1300 people), the flat management structure is surprising.

Integration may occur both within and outside the organisation. A step towards integration of companies, such as a manufacturer and its supplier and client companies, has been taken by implementing a strategy called Electronic Data Interchange (EDI) in the automotive manufacturing industries in the USA, Europe and Australia. This involves paperless transfer of business documents between participating companies (Baker 1988).

The current viewpoint on integrated components is that it should be planned 'top down' (that is, from corporate goals to shop floor), but implemented 'bottom up'. This approach requires firstly, the definition of corporate goals and then, based on these goals, the formulation of an integrated set of strategies such as marketing, financial and manufacturing strategies (Hayes & Wheelwright 1984, p.24-35; Samson 1991, p.19-20; Hayton 1990, p.23-28).

This approach was most evident at the Bridges Corporation who undertook three major steps in developing their competitive strategy. Initially, they determined existing corporate objectives and formulated clear business strategies. This involved reviewing the total operations of the company. Then, management staff were exposed to the principles and techniques associated with integrated manufacturing. Finally, a feasibility study was undertaken which considered factors crucial to the strategy's success (see Chapter 4).

Sigma followed a similar course, developing a strategic plan which aimed to implement the planned changes in an integrated and co-ordinated fashion.

APPLICATION OF CIM TECHNOLOGY

CIM is a technology which may form an important part of an integrated manufacturing strategy for a company and although it is a powerful tool it should be viewed in context - its potential is only realised in a well-planned integrated manufacturing strategy. Furthermore CIM technology is still being developed.

CIM uses computer hardware and software to provide the flow of all information between people and machines in a manufacturing organisation. Fully developed, CIM would result in little or no information being transferred orally or by documents, with all essential information being transferred and/or stored electromagnetically. This would embrace:

- management information;
- orders;
- accounts;
- design information;
- engineering information;
- production planning and control.

CIM technology formed an important part of each company's integrated manufacturing strategy. The Bridges Corporation especially were committed to the development of their CIM capabilities. A company-wide computer-based system was implemented to facilitate

information flow between the factory and the various other operations units in the company. Milford Fabricating Company has a fully integrative CIM system which provides flexible interfacing between CAD/CAM facilities and the manufacture and despatch of the final product to customer specifications.

CHAPTER 3: MANUFACTURING INDUSTRY TRENDS

The major industry trends in Australia are reasonably clear. In common with most other developed nations, Australia is experiencing the following changes to its economy:

- a major structural shift in employment from manufacturing to service industries (alongside industries with an expected shift to leisure/entertainment industries);
- the development of newer 'high-tech' industries (together with industries hundreds of years old), such as information technology, biomedical technology and aerospace industries, with an expected movement towards new materials technologies;
- a trend away from the mass production approach towards integrated manufacturing.

Each of these are medium to long-term trends, and each has important economic and social implications. Of particular importance are the implications for TAFE.

Within these major trends significant variations are apparent. For example, the trend towards integrated manufacturing is most marked in medium to large volume assembly factories, and more likely in large manufacturing organisations than small manufacturing organisations. (DITAC. 1990 p.16). Even within each particular manufacturing industry (e.g. car manufacturing, electronic consumer goods), trends are different for each stage of manufacture. The factory of the future will not exist - a variety of models will exist, such as the three shown in Figure 1.

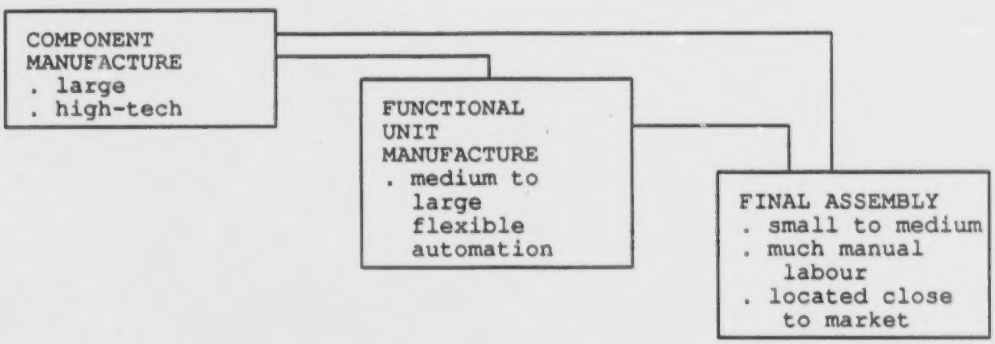

Figure 1: Three models of the factories of the future (Bolwijn & Kumpe 1988)

EMPLOYMENT IN MANUFACTURING COMPARED WITH SERVICE INDUSTRIES

Employment in the manufacturing industries in Australia has remained steady at a little over one million workers over the past ten years, whereas there has been substantial growth in employment in the service industries over the same period (see Table 1). Over the next ten years employment in manufacturing is expected to remain about the same while most of the growth in employment is expected to be generated in the leisure/entertainment industries, particularly in tourism and hospitality.

Even allowing for this change, employment in manufacturing in Australia is a substantial and important part of our economy. While manufacturing accounts for about 16% of Australia's workforce, it does help to support other associated 'industries', such as consulting services and vocational education and training services. Manufacturing also has a significant impact on Australia's balance of payments. In the 1988-9 financial year, manufactured goods accounted for a net deficit of $19.9 billion

towards Australia's balance of payments (see Table 2). The competitiveness of Australian manufacturing affects both imports and exports of goods; and new manufacturing equipment and technology are mostly imported. A recent report by the Australian Manufacturing Council warns that if Australia's manufacturing base shrinks any further, the economic gap will not be filled by tourism or the export of services such as education (Australian Manufacturing Council 1990).

'HIGH-TECH' INDUSTRIES

World markets (for both products and services) have grown more rapidly in the newer industries such as information technology, biomedical technology and aerospace industries - the so-called 'high-tech' industries. It is important to distinguish high-tech *products* (such as the computer chip) from high-tech *manufacturing techniques* (such as CAD/CAM), as sometimes the terms are confused. The development of these industries in Australia is important because of their growth potential and Australia's potential to succeed in certain niches of the high-tech markets. However, high-tech manufacturing techniques are of wider importance because they potentially affect <u>all</u> manufacturing industry, not just a small (though growing) part of it.

NUMBER OF EMPLOYED PERSONS (IN AUGUST OF EACH YEAR) BY INDUSTRY SUBDIVISION: AUSTRALIA ('000)		
YEAR	Manufacturing (% of total)	Total - all industries
1968	1,263.6 (25.0%)	5,055.6
1978	1,185.3 (19.9%)	5,969.6
1979	1,220.8 (20.2%)	6,041.5
1980	1,233.6 (19.7%)	6,246.7
1981	1,230.9 (19.4%)	6,356.3
1982	1,192.7 (18.8%)	6,347.6
1983	1,133.7 (18.2%)	6,232.7
1984	1,141.4 (17.7%)	6,462.3
1985	1,109.4 (16.7%)	6,646.1
1986	1,126.7 (16.4%)	6,885.7
1987	1,151.4 (16.3%)	7,073.2
1988	1,199.4 (16.4%)	7,330.1
1989	1,236.0 (16.0%)	7,727.6

TABLE 1: Employment in manufacturing in Australia

Source: *ABS Catalogue No. 6203.0: The Labour Force - Australia*

Note: *The real contribution of manufacturing to Australia's economy has not declined to the extent suggested by these figures because:*

- *significant gains in manufacturing labour productivity have been achieved over the period;*
- *employment in firms providing consulting services to manufacturers has increased over the period, and this employment is not included in the manufacturing subdivision.*

AUSTRALIA 1988-1989		
	MANUFACTURING TOTAL ($B).	SHARE OF ALL INDUSTRIES (%)
MANUFACTURING * GROSS DOMESTIC PRODUCT	51.5	17.4%
MANUFACTURED ** GOODS (IMPORTS)	43.7	92.9%
MANUFACTURED ** GOODS (EXPORTS)	23.8	54.8%
BALANCE OF TRADE	19.9 (DEFICIT)	-

Table 2: Contribution of Manufacturing to the Australian Economy

Source: * *ABS, National Accounts, CAT. No. 5220.0*
** *ABS, 1990 Yearbook*

THE TREND TOWARDS INTEGRATED MANUFACTURING

The main form of work organisation used in Australia and other industrialised nations up to now has been a pyramid structure with a strict hierarchy. This form was most apparent in large organisations which had as many as ten or more levels in the hierarchy. This form was underpinned by the management approach developed by Frederick Winslow Taylor in the 1880s and 1890s. Taylor, an American industrial engineer, developed a system of work which suited the large factories resulting from the Industrial Revolution. His principles of management are described in *The Principles of Scientific Management* published in 1911. The key features of the approach, now called 'Taylorism', are:

- strict hierarchical organisational structure;
- narrowly defined jobs;
- narrow range of skills required to perform each job;
- standardisation of methods by precise specification of every task;
- factory floor workers cut off from decision making;
- discouragement of social interaction among workers;
- authoritarian relations within the hierarchy; and
- strict supervision of workers.

The following quote from his work describes the underlying attitude:

> Under our system, a worker is told just what he is to do and how he is to do it. Any improvement he makes upon the orders given him is fatal to his success. (Taylor, 1911)

This approach generally achieved improved cost-efficiency but resulted in very low job satisfaction and loss of job control by those at the factory floor level. They were not allowed to contribute ideas or suggestions for improvement, and had no say in the management of the organisation. "Park your brains by the door" was the catch-phrase. Taylor's principles were applied to manufacturing and non-manufacturing organisations.

both large and small. The approach, though modified over time, is still widely used today in industrialised countries, particularly in larger organisations.

In manufacturing, Henry Ford early this century successfully added to Taylorism the features of:

- standardisation of products;
- large volume/low cost marketing; and
- flow-line assembly,

to give an approach also widely applied in industrialised countries this century. This approach to manufacturing is often referred to as 'Fordism'.

More recently, Taylorism and Fordism have been replaced by the integrated manufacturing approach in a small but increasing number of enterprises in Europe, North America and Australia.

This trend first became apparent in West Germany in the early 1980s. When Horst Kern and Michael Schumann (1987) identified the emergence of 'new production concepts', as opposed to Taylorism, in German industry where new computerised production systems were being installed. Michael Piore and Charles Sabel (1984) analysed world economic and social trends and concluded that a new approach to manufacturing, which they termed 'flexible specialisation', with roots in the traditions of craft production, was becoming a viable alternative for manufacturers in Western countries.

There are two major reasons for this trend towards integrated manufacturing:

- the sophistication of world markets; and
- the availability of computer technologies.

These two factors are discussed below; following this, aspects of the trend towards integrated manufacturing are discussed, including CIM and work organisation.

SOPHISTICATION OF WORLD MARKETS

The general trend in recent years has been away from markets where price is the main component of competitiveness, to customer-oriented markets where price, quality, service and flexibility are equally important components (Bolwijn et al. 1986, p.133; Brodner 1987, p.32).

Japan has capitalised on this trend, turning their quality weakness in the 1950s and 1960s into quality becoming their major strength in the 1970s and 1980s.

The concepts of service and flexibility include:

- the development of new products and services to closely match customer demands;
- fast responses to changes in demand;
- shorter and more reliable lead times from order to delivery; and
- good after-sales service.

In other words, companies need to know exactly what customers want and to be able to deliver quickly, a matching range of products.

In the 1960s those companies most efficient in terms of producing goods and services at lowest cost were usually the most successful. In the 1990s however this formula will not necessarily guarantee success. Consumers are now seeking a combination of low cost, high quality and high service in their product.

It is expected that product or service innovation will become an increasingly important factor in competitiveness in the 1990s (Bolwijn & Kumpe 1988; Samson 1990). Innovation includes:

- new products or services;
- modification of existing products or services; and
- new applications of existing products or services.

Innovation also may refer to new ideas about processes or systems within the company. Innovation requires:

- creativity;
- correct allocation of resources;
- understanding of technology, competitors and markets;
- good management of projects;
- the appropriate business structure and culture; and
- a measured amount of risk-taking.

The customer is a good source of new product ideas, so spending more time with customers and researching their needs could improve quality, service and innovation.

By world standards Australia is a very creative and inventive country. But many of our good product ideas go to overseas manufacturers. Our weakness lies in getting good product ideas to the market. As we have seen, successful marketing requires good business sense to back up the good ideas; it also requires financial backing.

The concept of sophistication of markets includes four main components of competitiveness in the 1990s, with one of them, innovation becoming important. The general trend from the 1960s to the 1990s is shown in Figure 2.

The relative importance of each component of competitiveness will vary from product to product and service to service. However, these components are applicable in most industries and across most organisations - large and small.

Each company or organisation may choose a different competitive strategy, attempting to excel in one or two of these components while giving a lower priority to the others. In the long-term, companies that implement an integrated manufacturing approach may have the ability to excel in all simultaneously. However, Bolwijn and Kumpe (1988) see the achievement of these four components within a manufacturing company as cumulative (as indicated in Table 3), and warn that a company restructuring cannot successfully transfer from one phase to another phase unless it at the same time aims for the next phase. For example, the 'quality firm' based on communication and co-operation cannot move to the 'innovative firm' based on participation and democratisation without first moving to the 'flexible firm' based on integration and decentralisation. (See Table 3).

AVAILABILITY OF COMPUTER TECHNOLOGIES

The application of computer technologies in manufacturing has enabled manufacturers to achieve low cost and flexibility at the same time. In the past, equipment based on new technology usually offered one or more of the following benefits:

- greater production rates;
- integration of two or more (previously) separate processes;
- automation, with reduction of manual labour.

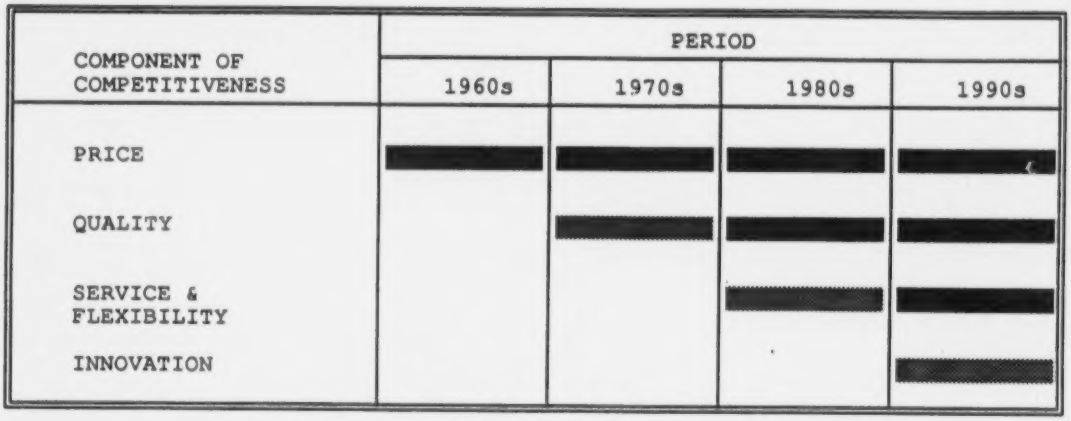

Figure 2: The changing components of competitiveness (adapted from Bolwijn et al 1986, p.133; Hayton & Harun 1988, p.29)

ORGANISATIONAL PHASE	PERFORMANCE CRITERIA	STRUCTURE/CULTURE REQUIREMENT
Efficient Firm	efficiency	specialisation and hierarchical organisation
Quality Firm	efficiency + quality	communication and co-operation
Flexible Firm	efficiency + quality + flexibility	integration and decentralisation
Innovative Firm	efficiency + quality + flexibility + innovative ability	participation and democratisation

Table 3: The four phases of development for a manufacturing organisation (adapted from Bolwijn & Kumpe 1988)

This improved efficiency, but flexibility usually was not enhanced. A key factor in flexibility is the ability to produce quickly, small batches of many different products. The technologies were most effective for continuous operation or long batch runs. The technologies usually could not be fully exploited for short batch runs because of the cost and time required to set up each different production run.

The introduction of computer technologies in recent years has reduced the cost and time required to reset production (Piore & Sable 1984, p.258-261; Higgins 1986, p.35; Hayton & Harun 1988, p.15-19). Examples of such computer technologies are:

- computerised numerical control (CNC) machines;
- computer aided design (CAD);
- computer aided manufacturing (CAM);

- computer technologies applied to materials transport;
- programmable robots for assembly and other production processes;
- computerised production control.

These technologies will be particularly useful to medium to large volume assembly industries (category 2 in Table 4), by allowing high productivity and flexibility.

Philips Radio Communications Systems in Cambridge used a sophisticated computerised production control system to give maximum flexibility in manufacturing. A batch size of one has been achieved in the final assembly production centres here (see Chapter 4).

Sigma Air Conditioning used a combination of CAD, CNC and MRP-II to greatly reduce lead times while designing and producing very small batches of railroad air-conditioning systems (see Chapter 4).

1. SMALL VOLUME ASSEMBLY (1 to 100 units per month*)

   e.g. medical equipment
   telecommunications equipment
   scientific equipment

2. MEDIUM TO LARGE VOLUME ASSEMBLY (100 to 10,000 units per month*)

   e.g. clothing
   structural metal products
   sheet metal products
   hand tools
   automobiles
   video and audio equipment
   electronic equipment
   household appliances
   water heating systems
   industrial machinery and equipment
   plastic and related products

3. VERY LARGE VOLUME ASSEMBLY (over 10,000 units per month*)

   e.g. printing
   metal fasteners

4. PROCESSING INDUSTRY

   e.g. food processing
   pharmaceuticals
   textiles

*Notes: 1. Volumes refer to the number of units of each product produced in a month by the largest producers in Australia.

2. The above classification is based on classes within the Australian Standard Industry Classification, (1983).

Table 4: A classification of manufacturing industry by product type and volume of production

INTRODUCTION TO CIM

One of the original objectives of some of those who developed computer integrated manufacturing (CIM) technologies was the attainment of the 'lights out' factory in which there are no operators and all manufacturing operations are undertaken by machines controlled and linked by computer systems. Some writers in the early 1980s stated that CIM and related manufacturing technologies would lead to a reduction in the skills required on the shop floor and eventually lead to the widespread occurrence of the lights out factory.

However, it is now widely acknowledged that while the 'lights out' factory is now technically feasible, a more competitive and realistic approach is a combination of CIM technology (or technology components of CIM), and integrated types of work organisation (described in the next section) which rely on skilled people at all levels in the organisation.

The experience of IBM in North Carolina illustrates this point. IBM has a large manufacturing plant in the Research Triangle near Raleigh, North Carolina in the USA. In 1987 a new assembly line was developed to produce a new personal computer model. The most up-to-date robotic technology was applied to develop a complete assembly and packaging line requiring no human operators. It took a team of engineers and technicians two years to develop and perfect the plant. The plant then was in full production for a further year before it was dismantled - market forces resulted in the model being discontinued! Management staff at the factory now believe that quick development start-up and change of production lines are important in today's market, and that these are best achieved with a combination of operative staff and robots in the assembly and packing lines. They also have operatives working in teams or closely together to improve social interaction and job satisfaction.

The implementation of full CIM by manufacturers to cover all functions of the manufacturing organisation is fairly rare, even in the USA, where much of the development of CIM has occurred.

In Australia, a survey by the Australian Bureau of Statistics indicated that in 1988, the implementation of components of CIM, such as CAD, CAM and robots was low. Approximately 33% of manufacturing establishments with 10 or more employees had acquired at least one advanced manufacturing technology (AMT) up to June 30th, 1988. The most commonly acquired technology was programmable logic controllers (PLCs), with 14% of establishments having this technology, and the lowest being robotics and flexible manufacturing cells, both with 1%. It is notable, that of the firms who had not already incorporated simple robots, only 4% planned to do so in the next five years. Presently, only 10% of companies are using basic CAD technology, and only a further 11% plan its introduction in the next five years (ABS, 1989 p.1-2).

CHANGES TO WORK ORGANISATION

One of the key features of the trend towards integrated manufacturing is the change from a Taylorist or Fordist approach to work organisation (described earlier in this chapter) to an integrated type of work organisation.

Integrated work organisation displays the following features:

- flatter management structure with fewer hierarchical levels;
- skill broadening with less specialisation;
- smallness of scale (organisations become based on economy of scope rather than economy of scale);
- team-work where a small group of workers performs multiple functions.

When the goal is integration and better communication through most or all of these approaches, integrated work organisation will be the result. A simple integrated organisational structure based on two semi-autonomous teams is illustrated in Figure 3.

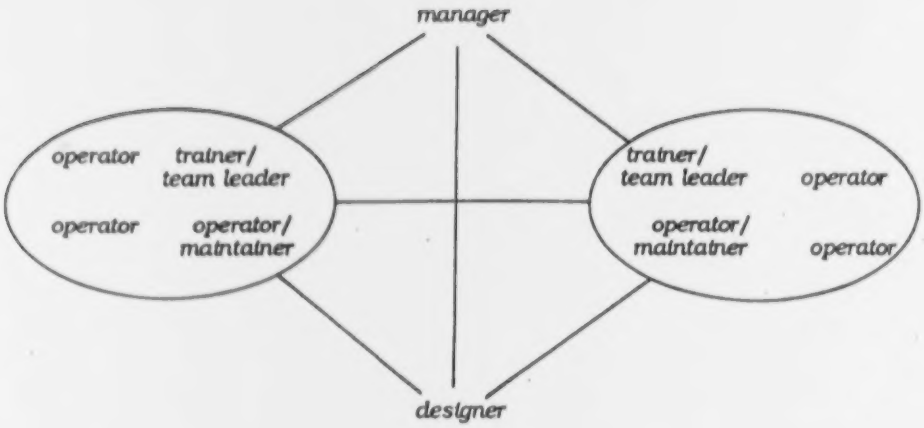

Figure 3: Example of work organisation with two semi-autonomous teams.

The skill requirement for each member of an organisation using this approach is such that there is a need for:

- a higher level of skills overall;
- a broader band of skills (including possible skilling across functional boundaries such as production - maintenance - design boundaries and across traditional trade boundaries);
- better interpersonal and team-work skills.

Important outcomes claimed of these approaches to work organisation are the ability of the organisation:

- to use some new technologies more effectively and efficiently, particularly those involving equipment that combines mechanical, fluidic and electronic systems;
- to allocate staff to a wider variety of tasks (particularly useful for small organisations);
- to use modern concepts of quality management and improvement;
- to respond faster and more effectively to market demands.

Only some aspects of integrated work organisation had been implemented by each manufacturer included in this study. The Human Centred CIM project in the U.K. (described in Chapter 4) is undertaking much development work on the application of semi-autonomous teams to metals manufacturing, and some Australian manufacturers are studying the application of this. Most of the manufacturing case studies had implemented flatter management structures and skill broadening.

Much supporting work still needs to be undertaken in the areas of job redesign and (in Australia), 'restructuring' of industrial awards in order to effectively introduce significant changes to work organisation towards integrated approaches.

CHAPTER 4: CASE STUDIES OF MANUFACTURERS

INTRODUCTION

Six case studies of manufacturers are described in this chapter. They include:

- Sigma Air conditioning (Lidcombe NSW): Sigma is a batch manufacturer of railroad and off-road transport air conditioning systems, and employs 200 people. Sigma has an integrated manufacturing plan which is nearing full implementation;
- Bridges Corporation (Wingfield SA): Bridges, through its subsidiaries, produces electrical switchboards and enclosures, moulded reinforced plastic products and micro-irrigation products and employs approximately 400 people Australia wide. As with Sigma, Bridges Corporation is in the final stages of implementing its integrated manufacturing strategy;
- Philips Headquarters (Eindhoven, Netherlands): Philips is a major, multi-national producer of electrical and electronic products and employs approximately 336,700 people worldwide. Philips is endeavouring to move toward a strategy of increased flexibility and innovation;
- Philips (Cambridge, UK): Philips in Cambridge is the world headquarters for Philips Radio Communication Systems (PRCS), and employs 1879 staff. Considerable emphasis is placed on flexibility and quality, with all employees being involved;
- Milford Fabricating Company (Detroit, Michigan, USA): Employing 450 people, Milford Fabricating Company undertakes a range of prototype work for the automotive, aerospace and various other industries. Milford's strategy involves encouraging a highly skilled and flexible workforce;
- Human Centred CIM Systems Project - (Espirit 1217): This project is a collaborative research study dedicated to developing semi-autonomous work teams for application in production and industry. Eight partners from three European countries formed a consortium to promote human-centred work environments.

Key issues from these case studies are discussed in *Chapter 6: Skills Required.*

Case Study: SIGMA AIR CONDITIONING PTY LIMITED, Lidcombe NSW.

INTRODUCTION

Sigma Air Conditioning is a batch manufacturer of railroad and off-road transport air conditioning systems. The Sigma factory is located in Lidcombe, a western suburb of Sydney. Sigma has grown rapidly over the past decade, with staff increasing from 40 to now more than 200, and turnover increasing from $744,000 to $14 million a year.

The company has the dominant share of the domestic railway air conditioner market and is successfully developing export markets. Most of the company's sales are won by tender.

WHERE THE COMPANY CAME FROM

In 1984 the company had close to a complete monopoly of the domestic railcar air conditioner market. However, its market position was not completely secure. There was an increasing threat from overseas suppliers.

Sigma perceived then that its main weakness was lead times. Lead times on preparation of tender took several weeks; lead times on prototype design to first-off unit took up to 12 months, using conventional design, drafting and production methods; lead times on order entry to product delivery took an average of eight weeks, and there was no formal order entry system in place.

Quality was also perceived as a weakness. Sigma undertook final product quality checks but there was no system of in-line quality control. Thus, quality problems were not quickly identified and the sources of problems often could not be pinpointed.

The company believed that it also needed to reduce its manufacturing costs to remain competitive. One aspect of manufacturing which contributed greatly to cost was inventory level. In 1984, Sigma's inventory level totalled $3.6 million.

Work organisation and job design at Sigma displayed a traditional hierarchical structure with mostly specialised operative and trade jobs. Nearly all the employees were full-time and permanent.

COMPETITIVE STRATEGY

In 1984 the Board of Sigma and the senior management recognised the vulnerability of its dominant market position. They subsequently developed a competitive strategy with four main goals:

- reduction in lead times (design, tendering and manufacturing)to improve service to customers;
- improvement in manufacturing flexibility;
- consistency in quality and quality improvement;
- reduction in manufacturing costs.

The overall goal was improved *long-term* profitability.

Initially, the company began investigating advanced manufacturing technologies and techniques. Then in 1984 the company joined the Integrated Manufacturing Demonstration Program (IMDP) of the Department of Industry, Technology and Commerce (DITAC). This resulted in the company spending more time developing a comprehensive strategic plan which involved the introduction of these technologies in a co-ordinated and integrated manner. Sigma's competitive strategy thus evolved into an integrated manufacturing strategy to fit the company's unique features and taking into account both technology and human aspects.

The plan was integration of manufacturing through two means:

- improved internal inter-personal communication by establishing cross-functional teams (e.g. designers and production engineers working as a team at the design and prototype manufacturing stages);

- a new internal electronic data communication system using the following elements:

  - computer mainframe,
  - CAD,
  - CNC machine tools,
  - Local Area Network (LAN) to link the CAD system with the CNC machines,
  - MRP-II inventory and production planning and control package.

The objective of the internal electronic data communication system was to develop a single easily-accessed electronic communication network so that those who create the tender information and those who plan and manufacture the products were all operating with the same data.

These initiatives were to be supported by a program of training for all employees. In the early stages, the training concentrated on senior managers, middle managers and supervisors.

The strategy was modified over time as some of the anticipated conditions changed.

The three main modifications were:

- installation of a Local Area Network (LAN) was delayed because of the high resources required to install it correctly, and because successful integration has been achieved by tapes generated by the post-processing capabilities of the CAD system. Separate integration of the financial, material and production control, design and distribution data through the MRP-II system has also been achieved;

- installation of MRP-II was delayed and done in stages because Sigma's manual stock control procedures were very inaccurate. It was found that the MRP-II package worked very poorly with an inaccurate stock control system;

- the amount of training required by operative and technical staff was much higher than expected.

Between 1984 and 1988, implementation of the strategy involved:

- expenditure of $1 million on computer hardware and software, with further computer work stations being purchased after 1988;

- investment in CAD and CNC machine tools on the factory floor. Investment in this area totalled $1.25 million and included Computervision work stations, a Trumpf Trumatic 260 turret punch and a Promecam CNC brake press;

- increases in stock because staged introduction of Sigma's MRP-II system exaggerated the usual increase in stock associated with the start up of MRP-II. It is only since June 1988 that stock levels have begun to decline on a regular monthly basis;

- staff training and re-training. The training and re-training program was a very costly exercise in the introductory stages of the project. There is now a need for a continuing, regular training program.

WHERE THE COMPANY IS NOW

Most of the targets set by Sigma as part of its strategy have been achieved. Lead times on tender preparation have been reduced. As was the aim, lead times on prototype design to first-off unit have been reduced by 30%. This has been achieved through the

introduction of CAD/CAM, MRP-II, improved factory layout to enhance production flow, and extensive training.

Lead times on order entry to product delivery have been cut from an average of 8 weeks to 5 weeks, and further improvement is expected. This exceeded the target reduction of 25%. It was achieved by:

- introduction of a formal order entry system;
- capital investment in CNC machine tools;
- re-arrangement of the factory layout;
- improved manufacturing methods, including smaller batch quantities and reduced queue and move times;
- co-ordination of sales and operations planning with a realistic Master Production Schedule (MPS);
- simplification of manufacturing by arranging into a single continuous (U-shaped) production line divided into a small number of zones of fabrication and assembly in which a small team of operators perform a complete module or stage of the manufacture.

Quality has improved in two main ways. Firstly, an in-line quality control system has been introduced by means of a job card and component checklist which follows each air conditioner through the factory. Each team must check quality before the air conditioner is handed to the team responsible for the next module or stage.

Secondly, Sigma has greatly reduced rework by introducing a formal recording system and then identifying problem areas and their causes. Sigma is also involved in a program to update its systems to conform with quality standards AS1822/AS3902.

Sigma has reduced inventory levels below the $3.6 million of 1984, but has not yet achieved the target reduction of 75%. The main ways of achieving reduction were implementation of an MRP-II system and a revised Master Planning Schedule. The main problem encountered was the very poor accuracy in inventory records. It has proved time-consuming to improve accuracy to the desired 98% level.

The full effect of Sigma's integrated manufacturing strategy is yet to be realised, but there are many indicators of its success so far. These are:

- slightly lower direct costs of production;
- greatly reduced indirect costs of manufacturing;
- stable profitability in an increasingly tight market;
- increased international competitiveness, evidenced by the winning of tenders for work in South-East Asia, and continuing dominance of the domestic market.

TRAINING

As shown earlier, training was recognised as a vital part of the integrated manufacturing strategy undertaken at Sigma but during implementation of the changes its importance and amount required were greater than expected.

This was particularly so for the factory floor operators. They were given training in the practical technical aspects of MRP-II but this was not enough. Operators viewed the more formal documentation needed for MRP-II as an unnecessary 'bureaucratic' function. Without full commitment to the system by all the operators, documentation did not attain the high level of accuracy required for success of MRP-II. Sigma then turned to 'education' rather than training. All operators were involved in discussions of <u>why</u> accurate documentation was important for MRP-II, why the success of MRP-II was

important to the company's competitiveness, and the customer-oriented philosophy of integrated manufacture.

Training for integrated manufacturing focused on the philosophy of integrated manufacturing, the principles of Advanced Production and Inventory Control Systems (APICS), and the practical skills required for MRP-II, CAD, CAM and CNC. A 'top down' sequence was used. That is, senior managers were trained first, then middle managers, then supervisors. Practical training involved a mix of these groups.

The education and training program used at Sigma to support integrated manufacturing has helped to give the company a more highly skilled and committed workforce. Operators have become multi-skilled, being trained on-the-job to perform functions in two or more fabrication and assembly zones at the factory. However, some specialised operative jobs have been maintained. In addition, some CNC operators have been trained. Factory staff have been retrained for a number of skilled jobs to fit Sigma's new manufacturing system. These include CAD engineers, CAM engineers and MRP-II practitioners.

THE FUTURE

The senior management of Sigma is convinced that it took the correct path as implementing an integrated manufacturing strategy. The strategy has been successful, and further improvements in productivity, quality, flexibility and service are expected in the near future. Consolidation of the changes will involve continuing training of operatives, award restructuring, and improvement of stock control.

The company's future strategy will involve greater emphasis on improvement (rather than control) through the Value-Added Management (VAM) approach.

Case Study: BRIDGES CORPORATION PROPRIETARY LIMITED, Wingfield SA

INTRODUCTION

The Bridges Corporation is a family-owned Australian manufacturing company. Through its operating subsidiaries B & R Products, Bramile and Wingfield Plastics, it produces electrical switchboards, switchboard enclosures, moulded fibre reinforced plastic products and a range of micro-irrigation products.

At the time of the case study, the Bridges group employed about 300 people at three manufacturing centres in Adelaide and Brisbane. Annual turnover is estimated in excess of $27 million.

By using an integrated manufacturing strategy, Bridges aims to improve its quality, cut lead times and provide the basis for long-term profitable growth.

WHERE THE COMPANY CAME FROM

Prior to its initial involvement with the Integrated Manufacturing Demonstration Program in 1982, Bridges experienced problems with poor quality, excessively long lead times, inconsistent and poorly integrated information systems and structural deficiencies in management were apparent.

The company hoped that the integrated manufacturing program would achieve the following benefits:

- a decrease in the cost of ensuring quality;
- reduction in actual overhead costs;
- decreases in lead times required to develop new products;
- improved manufacturing quality;
- improved business efficiency; and
- increased customer responsiveness.

The need for a more flexible workforce (especially shop floor operatives) was also recognised as an important part of the overall strategy.

COMPETITIVE STRATEGY

The competitive strategy adopted by the Bridges Corporation was determined once three crucial steps were taken:

1. Determination of existing corporate objectives and formulation of clear business strategies. To achieve this, a total review of company operations was seen as necessary from the shop-floor up.
2. Development of a strategic understanding of integrated manufacturing. To achieve this goal, middle and upper management were exposed to the philosophies and techniques underlying integration.
3. Finally, a detailed feasibility study was conducted that covered five core areas:
   - products (sales, quantity, contribution to gross profit);
   - plant manufacturing capability;
   - workforce profile by age, qualification, skills and training required;

- information system evaluation; and
- the nature and strength of the capital base was assessed.

Once these had been completed, the company pursued the following strategy:

- The establishment of an integrated information system which integrated the manufacturing, marketing and business functions of the company at all levels;
- The automation of interfaces through the development of a computer-based system to facilitate information flow between the factory floor and information systems;
- The introduction of CAD/CAM/CAE to support the product design, manufacture and marketing functions of Bridges. They have also invested in MRP-II although its benefits were not at the outset entirely obvious. Other elements include: CIM, CNC, JIT and FMS.

Bridges have also developed formal strategies. In marketing, the strategy was to focus on specific market segments, especially higher value-added lines where they are the least-cost supplier. There was also a focus on import replacement and export.

The next specific steps planned by the company include: further application of CAD/CAM, shop floor data collection, implementation of management by objectives and budget in all business units, and fully integrated management reporting. Other issues to be tackled relate especially to the increasing awareness of important manufacturing issues such as tolerances, limits and fits, and work instructions.

WHERE THE COMPANY IS NOW

As a result of the significant investments made in the area of integrated manufacturing, the current situation is as follows:

- the impact on cash-flow has been unfavourable due to the capital and operational expenditure involved with the initiatives;
- indirect labour costs have increased as capacity is presently ahead of demand;
- profitability is expected to increase considerably as a result of the recent investments;
- skill levels have increased considerably, as have employment levels. Trained staff have been employed in CAD, quality and other functional areas;
- the level of training has risen dramatically, as has the demand for it by employees.

The company expects the following benefits to flow on in the near future:

- an overall reduction in lead times of between 50% and 60%;
- improved new product specification procedures;
- improved inventory management;
- reduced scrap, waste and rework; and
- increased quality of product.

TRAINING

Bridges' participation in training has increased the skills and competencies of its employees which had historically been quite low. The present major training needs of the company are:

Non-trade (operative): The need for shop floor staff to appreciate the philosophies of integrated manufacturing, to engage in quality control activities and the use of numerically controlled machinery. Awareness of safety issues was also considered crucial to an operative's training.

Tradesperson: Generally the same as non-trade, except that communication skills are seen as a necessary requirement.

First Line Supervisors: Need to learn supervisory skills and issues related to occupational health and safety.

Technical Staff: Use of numerically controlled equipment and electronics seen as necessary.

Management: The need to understand materials management and the processes behind new product development was seen as crucial.

At an early stage, Bridges saw the need for considerable training for their technical level staff. The company indicated that the required level of competence necessary for technical staff (relating specifically to Integrated Manufacturing) ranged from basic awareness to actual practical skills acquirement. The following gives some detail of their current requirements.

Technicians require practical skills enhancement in:

- Computer Aided Design;
- Computer Aided Drafting;
- Numerical Control Programming;
- Quality Management Techniques;
- Just-in-Time Inventory Control;
- Integration of Computer and Manufacturing Hardware; and
- Maintenance of Integrated Manufacturing Systems.

Some introductory or basic awareness competency is presently required in:

- Numerical Control Operations;
- Computer Integrated Manufacture;
- Management Information Systems;
- General Computer Literacy; and
- Flexible Manufacturing Systems.

Presently, there is no skills requirement in the areas of new software development and Computer Aided Process Planning.

THE FUTURE

Bridges Corporation is totally committed to the implementation of its strategy. Further development of its CAD/CAM/CIM capabilities are planned in the next five years in conjunction with continued integration of its management, production, product development and marketing units. Training will naturally form an important part of its future strategy.

Case Study: PHILIPS HEADQUARTERS, EINDHOVEN, NETHERLANDS.

INTRODUCTION

The visit to the Philips Headquarters in Eindhoven, Netherlands was prompted by study of *Flexible Manufacturing: Integrating technological and social innovation* its five authors employed by Philips in Eindhoven. This book was one of the key references for the Centre's integrated manufacturing project (Bolwijn et al 1986).

Interviews were held with:

- Mr D Blom, Director, Personnel Management and Labour Relations.
- Mr J N A Vermeulen, Technical Training and Education.
- Professor T Kumpe, Organisation and Efficiency Department.

Professor Kumpe was one of the five authors of the book mentioned above.

Philips is a large, multinational company which manufactures a wide range of electrical and electronic products. In 1987 it had net sales of $A30 billion in the following product sectors (given in descending order of sales volume):

- consumer electronics;
- professional products and systems;
- components;
- lighting;
- domestic appliances;
- miscellaneous.

Philips employed a worldwide total of 336,700 people in 1987, distributed among the Philips companies in seven regions as follows (showing thousands of employees):

- Europe excluding Netherlands (139);
- Netherlands (70);
- USA and Canada (54);
- Latin America (33);
- Africa (5);
- Australia and New Zealand (3).

The main purpose of the visit to the Philips Headquarters was to identify Philip's current view of world trends in integrated manufacture and Philip's own strategy, and to discuss education and training responses required. Specific issues were to be followed up by a two-day visit to the Philips factory in Cambridge.

CORPORATE 'PHILOSOPHY'

Very useful detailed information was collected during the interviews, and booklets recently published by the Organisation and Efficiency Corporate Office were collected. These booklets contain very relevant information on manufacturing strategy.
After the interviews with three senior Philips headquarters staff, broad observations on Philips Corporate 'philosophy' are:

- the Philips headquarters staff consider it important to keep up-to-date with the concepts developed by the current major writers on manufacturing philosophy (e.g.

Goldraat, Hayes and Wheelwright);

- having learnt through hard experience, Philips corporate philosophy recognises that application of current manufacturing philosophies to each particular factory is the key to success but is not easy to implement (e.g. how to replace, through retaining, 40,000 blue collar workers with 40,000 white collar workers?);
- Philips have acquired a sound awareness of the strategies of their major competitors, including those in Japan;
- Philips sees Japanese manufacturers as the major competitive threat;
- Japanese strategies cannot be fully implemented in Philips because of cultural and political differences;
- there needs to be attention paid to both technical and social aspects of manufacturing - an emphasis on one without the other leads to failure;
- management needs to take the lead in the introduction of integrated manufacturing, but for many managers the 'cultural change' required is very difficult.

TRAINING POLICIES

Philips staff in Holland receive an average of 10 days training each per year. This represents expenditure of about 5% of direct salary costs, and compares favourably with the median of 2.6% for all industries in Holland.

In one Philips factory in Northern Holland it was found that 40 different training institutes were used by staff. This was seen as too fragmentary and education and training in Philips is now planned more thoroughly. It is felt that: "investment in people should be planned as carefully as equipment investment." Staff undertaking courses are now interviewed before, during and after the training program in order to evaluate the effectiveness of the training.

Two-thirds of Philips training is undertaken in-house. Training is roughly divided evenly between the following three providers:

- training conducted by Philips head office staff;
- in-house training by experts 'brought in' from colleges and private trainers;
- college-based courses.

For management and professional staff within Philips, the main training needs are in the areas of:

- project management;
- communication;
- 'attitude'.

For technical staff, the main training needs are in the areas of:

- project management;
- design for assembly (DFA);
- computer aided design (CAD);
- failure mode and effects analysis (FMEA).

For operative staff (including supervisors), the main training needs are in the areas of:

- information technology;
- quality;
- occupational health and safety;
- logistics (e.g. OPT, FMS).

Case Study: PHILIPS - CAMBRIDGE, ENG.

INTRODUCTION

The attractive and historical city of Cambridge in the United Kingdom is less than two hours drive north of London. Cambridge is one of Britain's leading high-tech 'basins' which includes Cambridge University, three Science Parks, a Techno Park and a Business Park.

The Philips plant in Cambridge is co-sited with the world headquarters for Philips Radio Communication Systems (PRCS), and is one of eight production and supply centres for PRCS around the world. The eight centres and the products of each are listed in Table 5. A very wide range of radio communications products is produced by PRCS, including pagers, cellular phones, and fixed, mobile and portable two-way radios.

PRCS is one of four business units within the Telecommunications and Data Systems Product Division of Philips. The other three business units are:

- Public Telecommunications;
- Business Systems (PABX, data systems);
- Dictation Systems.

The Cambridge plant has 1 215 employees with an additional 164 staff in the corporate headquarters. The sales turnover of the plant is about 100 million pounds sterling per year, represented by 175 000 produced units per year. The Cambridge factory comprises three main production areas (called 'technical centres'):

- surface mount assembly; and
- two separate product assembly and testing areas.

LOCATION	PRODUCTS
Cambridge	Pagers, Portables, Mobiles, Fixed private mobile radio and (from late 88) Cellular public mobile radios
Copenhagen	Cellular mobiles and portables, (Public navigational aids (Decca), (Later Satellite)
Melbourne (Clayton)	Mobiles and fixed (private mobile radio), Mobiles cellular (public)
Nuremberg	Mobiles for Germany; Cellular base stations
Dublin	Antennas, Filters, Combiners
Paris	Trunked private mobile radio systems
Johannesburg	Mobiles and portables (private), local market only
Manaus, Brazil (mid 1989)	(Tax free zone), local market only; mobiles and portables

Table 5. Philips radio communication systems: (Corporate centre is in Cambridge)

The management structure of the Cambridge plant is shown in Figure 3. The structure has few levels in the hierarchy, considering the size of the plant with over 1200 employees. It includes a number of off-line specialised service departments in addition to the three production departments, which are called 'technical centres'.

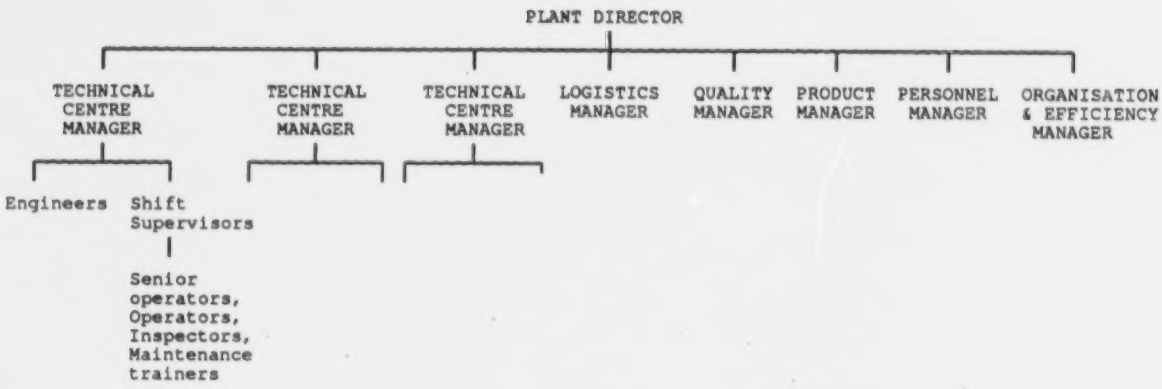

Figure 4: Management structure at Philips Cambridge plant

WHERE THE COMPANY CAME FROM

The company was started in Cambridge late last century by W.G. Pye. The Pye company steadily grew and diversified until it was acquired by Philips in 1967. It thus became part of the very large multi-national electronics manufacturing conglomerate of Philips.

The radio communications systems business unit of Philips has enjoyed sales growth in a rapidly expanding world market. However, in recent years its market share in many product lines has remained stable or declined.

COMPETITIVE STRATEGY

The company's goals are those of improved productivity, zero defect product quality, improved flexibility, shorter lead times for development and manufacturing, an annual growth rate of 15 per cent and an increase in export over UK sales.

The main strategies for achieving these goals at the Cambridge plant are Company Wide Quality Improvement (CWQI) and flexible manufacturing through integration of production control data. Key elements of these strategies are training and, to a lesser extent, automation.

Company Wide Quality Improvement is seen as a crucial strategy for the company. Two important elements of CWQI are quality circles and training. A quality circle is a small group of employees who meet regularly, on a voluntary basis, to identify and analyse work-related problems and recommend solutions. Quality circles may operate within any department of the company. In the production centres about 20% of the employees are members of quality circles, whereas in the non-production departments about 4% of the employees are members. Corrective Action Teams, with membership across departments, have been established to deal with specific problems.

A wide range of training programs have been developed to support CWQI. Programs include:

- understanding CWQI (half-day program for all employees);
- quality circle leader training course (two days);

- quality decision-making and problem-solving.

To demonstrate the company's commitment to quality, the plant director attends at least the first part of all Philips quality courses for employees.

Philips believes that attainment of quality and flexibility in manufacturing requires a plant level system and as well as support by individual employees. Support by operators requires both the possession of necessary skills (acquired through various training programs) and personal commitment. To encourage commitment, the salary of operators is based on:

- production output (40% weighting);
- quality (40% weighting);
- flexibility (defined as the range of skills and willingness to undertake a variety of tasks (20% weighting).

Flexibility is an important competitive strategy of Philips at Cambridge. By integrating manufacturing data, product design to simplify assembly, and training of operators, Philips have achieved greatly reduced lead times from order to delivery. With a production volume of 175 000 units per year and a wide range of products, the plant now operates on a batch size of one!

Figure 4 illustrates the main lines of manufacturing data flow and data integration at Cambridge.

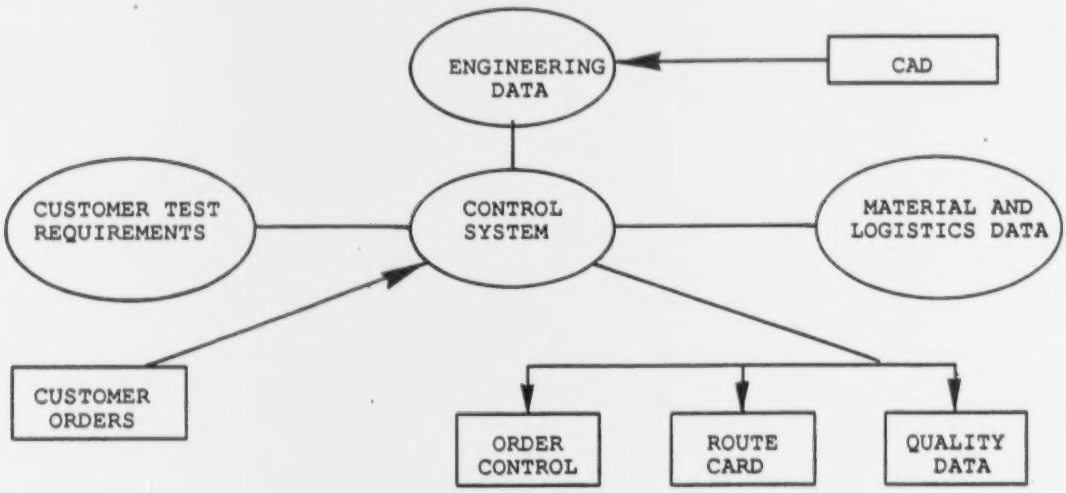

Figure 5: Manufacturing data flow at Philips Cambridge plant

The route card is a key element of the flexible manufacturing method at Cambridge. The card is a computer printout of data on materials, components and sequence of assembly. It guides the operators on the assembly of the product and the next destination for assembly or testing.

Compared to other electronic manufacturing plants, there is little automation at Cambridge. Although there are some sophisticated robots in the surface mount assembling area, and an extensive conveyor system for distributing work-in-progress around the other production centres. Assembly and testing at Cambridge are labour-intensive. The key technology in the plant is the manufacturing data control system.

TRAINING

Philips Cambridge plant carefully train recruits and annually appraise employees to:

- achieve high employee retention rates;
- increase flexibility of each employee;
- develop the skills of all employees, particularly team-work and interpersonal skills.

Operators are selected for dexterity, good hand-to-eye coordination, social/team skills and communication skills. Technicians are selected for high skill levels (usually indicated by educational qualifications such as the Higher National Diploma) and breadth in their range of skills. Graduates are selected for particular specialised skills in demand at Philips, interest and willingness to broaden skills, and a 'business view'.

Training and development are seen by management as having important roles. Training of operators mainly involves:

- induction;
- operations;
- first line maintenance;
- quality improvement;
- bottleneck management and process control;
- basic communication (2-day residential course); and
- computer literacy.

Senior operators also undertake the 'training within industry' courses offered by the Department of Trade and Industry, and quality circle leader courses.

Training of testers chiefly involves upgrading of technical electronic knowledge at the local further education college. Operators with interest in a career step into testing are encouraged and offered training in electronics.

Supervisors are offered short courses in quality improvement, quality circle project team leadership, discipline, handling of grievances, and counselling. They also receive on-the-job training in bottleneck management and material flow.

Engineers and other professional level employees are given cross-functional work experience to broaden their skills. A mentor is appointed to help with career planning for each person.

Case Study: MILFORD FABRICATING COMPANY

INTRODUCTION

Milford Fabricating Company is located at Detroit in the state of Michigan, U.S.A. Of its 450 employees, about 75 are 'salaried' employees, the majority of the other employees being skilled tradespeople.

The company undertakes a wide range of prototype and experimental work for the automotive, truck, aircraft, aerospace, farm implement, home appliance, office equipment and recreational industries. Its main market is automotive prototyping for the large US car manufacturers which have large plants at Detroit. For example, the company recently made 75 prototypes of the planned 1993 Ford Mustang. Milford has the capacity to convert original concepts, models or drawings into prototypes. Milford also experiments with new materials and innovative manufacturing techniques.

The main components of competitiveness for Milford are:

- quality (particularly accuracy of design and dimensions);
- meeting project deadlines;
- flexibility (the ability to incorporate frequent design changes quickly and easily);
- compatibility with the customer's technology.

Milford's strategy for achieving competitiveness has two main elements:

- CAD/CAM technologies; and
- a highly skilled workforce.

The wide range of CAD/CAM technologies gives flexibility and compatibility with customers. Milford makes use of most major CAD systems used to design both two- and three-dimensional computer models. Milford also has a full capacity to scan from models or digitize from drawings.

The Milford CAD/CAM system includes:

- computer maths surfacing;
- CNC cutter path generation;
- automated inspection certification; and
- computerised laser metal cutting.

Processes include CNC milling, sheet metal stamping, compression-moulding and injection moulding of plastics, and metal casting.

TRAINING ISSUES

Milford uses a number of methods to ensure that a highly skilled workforce is maintained. This strategy has contributed to competitiveness in quality, flexibility and innovation. Most of the shop-floor operators at Milford have at least a trade qualification.

To build up the skilled shop floor workforce, Milford offers apprenticeships in:

- tool and die;
- sheetmetal;

- casting.

Three maintenance apprenticeships are also offered in:

- heating and airconditioning;
- electrical;
- machine repair.

All new recruits must have a minimum education of full high school graduation. Milford sees this as ensuring that their employees have ability and interest in further education and training, and good basic communication.

Operatives at Milford undertake the following training, in addition to the initial trade course:

- CNC machining training from equipment supplier;
- CIM, CAD/CAM, CNC machining, communication and drafting from the Oakland Community College.

For example, in 1989 22 employees undertook course components from the computer integrated manufacturing associate degree at Oakland Community College.

'Cross-skilling' through additional training and movement among work centres is encouraged at Milford. Workforce flexibility is important to achieve and improve upon, project deadlines. The plant superintendent commented that Milford can move people freely among work centres because they have a 'non-union shop' and because of their training policy.

Milford's competitive strategy, based on CAD/CAM technologies and a highly skilled and flexible workforce has been very successful. They are the largest prototyping company in Detroit and claim to be the largest such company in the world.

Case Study: HUMAN CENTRED CIM SYSTEMS PROJECT - (ESPIRIT 1217)

INTRODUCTION

The Human Centred CIM Project is a collaborative research study with the ultimate goal of introducing flexible manufacturing cells to production and industry. Eight partners from Britain, Denmark and West Germany formed a consortium dedicated to enhancing the capabilities of employees by developing human centred work environments.

The project which was begun in May, 1986 involved:

CAP - Computer aided production - The German team developed a factory information system designed for production planning, scheduling and control.

CAD - Computer aided design - The Danish group developed a new means of design using an electronic drawing machine that interfaced directly to existing CAD packages or work stations.

CAM - Computer aided manufacturing - The British Group developed prototype turning cells with CNC lathes and handling equipment.

THE CONCEPT

Essentially human centred manufacturing involves people working within and managing manufacturing cells. These people are highly skilled and are required to manage all activities within each cell, and to be capable of troubleshooting.

These production cells aim to improve mechanistic efficiency by transferring much of the production planning and scheduling activities to the shop floor. Perceived advantages of such an approach include:

- simplified factory layout with improved scheduling;
- factory throughput optimised and 'bottlenecks' identified;
- shorter lead times, reduced scrap and stocks;
- improved due date performance (JIT); and
- increased inventory control.

The work cell, composed of a small team of approximately 2 to 5 operators who are highly focused and quasi-autonomous, are responsible for day-to-day management, machine setting operations, quality control and first line maintenance.

Each cell is product- rather than process-oriented and is responsible for manufacturing families of products. This procedure simplifies the scheduling of work between cells at the shop floor level. Actual work in progress, lead times and stocks in store are then reduced resulting in improved customer service.

TRAINING ISSUES

Training is required within the actual work process (action-based learning) and also for understanding the work process (knowledge-based learning). Specific requirements are:

Operator level: The need for a more highly trained, flexible and multi-skilled operative is crucial. This can be achieved by involving everyone in the development of the Integrated Manufacturing System. Using this approach, each person would be provided with general knowledge of the whole production process, and should have the opportunity to comment on any aspect of it. Specific training would be necessary in the following tasks:

- CNC machine programming and troubleshooting;
- micro-scheduling of the machine batches;
- all aspects of tooling; and
- communications with CAD and CAP manual operations.

Finally, the need for both on-the-line and off-the-line training based on the philosophy of 'learning by doing' would be reinforced.

Management level: Managers need to understand the principles of work organisation based on production cells. The ability to explore many of the facets of cell operation while monitoring cell operation efficiency is necessary ongoing training at this level.

Personnel at all levels would be encouraged to develop new skills in areas outside their traditional skill base.

CHAPTER 5: CASE STUDIES OF EDUCATIONAL INSTITUTIONS

INTRODUCTION

Seven case studies of educational institutions are described in this chapter. They include:

- Lehigh University CIM Laboratory (Bethlehem, Pennsylvania USA): Lehigh is a coeducational institution that is noted for excellence in engineering. Two major initiatives, the Centre for Design and Manufacturing Innovation (CDMI) and Manufacturing Systems Engineering project (MSE) form the basis of an advanced CIM laboratory. Their major focus is on post-graduate research, seminars for industry and tailored project work and consulting services for industry;

- North Carolina State University (Raleigh, North Carolina, USA): North Carolina State has established two major initiatives as a result of concern over the decline in US manufacturing; they are the Integrated Manufacturing Systems Engineering Institute (IMSEI) and the Industrial Extension Service (IES). In much the same manner as Lehigh, considerable emphasis is placed on post-graduate research and industry- specific projects, as well as seminars on various aspects of CIM;

- Ngee Ann Polytechnic (Singapore): Ngee Ann Polytechnic offers below degree level courses in engineering and commerce and specialises in advanced level CIM training;

- Coventry Polytechnic (Coventry, UK): Coventry Polytechnic offers manufacturing systems engineering courses from diploma to post-graduate level that have three broad components; engineering, business and management;

- German-Singapore Institute (Singapore): The German-Singapore Institute, through various local and international links with industry, has established several technical laboratories, and offers a Diploma in Production Engineering. The Institute emphasis close links with industry through practical student projects for industry;

- CIMM Centre (Regency Park, SA): Located at the Regency College of TAFE, the Computer Integrated Manufacturing and Management Centre provides an extensive range of facilities. Managed by the School of Mechanical Engineering in association with the Advanced Technology Education Centre (ATEC), the Centre fosters links with industry, other training providers and provides project support and training.

- Oakland Community College (Oakland, Michigan USA): Oakland Community College offers five associate degree courses for people in manufacturing including a course in CIM. The College has formed a partnership with IBM and other equipment suppliers to provide a high level of equipment and technical expertise. The College also offers specific short courses to industry.

Key issues from these case studies are discussed in *Chapter 7: Training Responses.*

In addition to these case studies, further descriptions of Australian educational institutions offering training in Integrated Manufacturing are given in a report prepared for the Office of TAFE in Western Australia (Badham & Wilson 1989).

Case Study: LEHIGH UNIVERSITY CIM LABORATORY

Lehigh University is an independent coeducational institution located in Bethlehem, Pennsylvania. Founded in 1865, Lehigh has long been noted for excellence in science and engineering. Enrolments at the University presently stand at approximately 4 300 undergraduates and 1 800 graduates.

Lehigh University, particularly those departments associated with the Manufacturing Systems Engineering (MSE) project have a symbolic relationship with local industry. This allows graduate students the opportunity to apply advanced technology concepts to an industrial environment, while at the same time providing industry with the expertise necessary to implement high technology manufacturing techniques to improve their productivity.

Two major initiatives at the University, the Centre for Design and Manufacturing Innovation (CDMI) and the Manufacturing Systems Engineering project form the basis of the larger CIM laboratory, or Intelligent Systems Laboratory.

The CIM Laboratory is an IBM-funded program for training manufacturing engineering graduates and is a key location for high technology manufacturing research and development. The Centre has acquired significant equipment from IBM grants, industry and educational institutions, and includes:

- ECO Maier 3-axis milling machine;
- Kearney & Trecker 3-axis milling machine;
- CADAM/CATIA/CAEDES engineering software;
- IBM PC XT 3270 microcomputers in conjunction with various work stations;
- Scara, IBM and Unimate robotics; and
- various plotters and graphics units.

The result is a fully integrated manufacturing system, that combines the management, research, design and manufacturing environments into interconnecting units.

CURRICULA

The University offers Master of Science degree programs in Manufacturing Systems Engineering. These are coupled with the major engineering departments such as Industrial, Mechanical and Computer Engineering. Designed as a one-year full-time program, it requires 30 hours of graduate study and provides extensive training in CAD, CIM, robotics, simulation and advanced manufacturing techniques.

Customised seminars and short courses are also offered to industry. Specific areas include:

- Manufacturing/Industrial Engineering;
- Just-in-Time Inventory control;
- Fundamentals of CIM;
- Total Quality Control; and
- Flexible Manufacturing Systems.

TEACHING APPROACH

The short courses are provided on a needs basis and have the feature of 'hands-on' demonstration and training. These are supplemented by advanced demonstrations from research engineers to illustrate specific applications. A similar approach is employed in the Masters program.

LINKS WITH INDUSTRY

Some 14 companies presently fund the Laboratory's operations in conjunction with contract research funding and educational sources. Specific project research, tailored seminars/courses and input to the Laboratory's activities are some of the benefits enjoyed by participating companies. Within the grant framework, emphasis has been placed on applied research with the industrial partners to improve the competitive status of US industry.

The Laboratory also conducts short 'diagnostic studies' for individual companies and government authorities, especially in these areas which expand the present range of analysis and simulation modelling available for industry applications.

The IBM Grant System equipment serves a central role in the development of the state-of-the-art flexible manufacturing laboratory. Course content and equipment is to be upgraded as technology evolves from the present CAD/CAM systems to the more complete CIM system.

Case Study: NORTH CAROLINA STATE UNIVERSITY - INITIATIVES IN INTEGRATED MANUFACTURING

The North Carolina State University has established two manufacturing institutions in response to the growing national concern over decline in manufacturing productivity in US industry. Both emphasise a multi-disciplinary and education/industry co-operative approach.

INTEGRATED MANUFACTURING SYSTEMS ENGINEERING INSTITUTE (IMSEI)

IMSEI was established in 1984 as an IBM/University joint initiative with the objective of assisting industry to improve its manufacturing capabilities and competitiveness. The Institute's major goals include:

- providing graduate level education and practical training in integrated manufacturing systems engineering;
- bringing industry and University expertise together to develop and implement advanced manufacturing systems; and
- promoting interactive technology transfer between educational research and industry applications.

CURRICULA

IMSEI offers a Master's degree in Manufacturing Systems Engineering requiring a minimum of 27 hours graduate course work and 6 hours of a research project that can be completed as part of an Institute project. Courses are conducted in the fields of:

- Computer Aided Manufacturing (CAM);
- Design for Automated Assembly (DAA);
- Manufacturing Operations Management;
- Design of Systems Programs; and
- Capital Investment/Economic Analysis.

These are concentrated into further sub-themes such as:

- robotics and artificial intelligence;
- information handling;
- mechanical design for automation;
- manufacturing automation; and
- sensors and control.

Approximately 60 students have graduated with the Master's Degree since the Institute's inception in 1984.

TEACHING APPROACH

As previously mentioned, there is both course and project work involved. Emphasis is on practical projects related to actual industrial requirements. The projects are integrative, frequently requiring team work and are of an inter-disciplinary nature. The Institute also conducts industry seminars, general research and enhancement projects funded by individual member companies.

EQUIPMENT

With an annual budget estimated at $750 000, IMSEI has extensive computer and laboratory facilities which include: CAD, CAM, flexible manufacturing, robotics and CIM provided by suppliers such as IBM.

INTERACTION WITH INDUSTRY

The program is sponsored by an industrial group of member companies. Nine member companies presently give support to the Institute and provide mechanisms for technology transfer between the University and industry. Specific project work, influence on project selection, quarterly and annual reports are some of the benefits derived from being a member company.

INDUSTRIAL EXTENSION SERVICE (IES)

The IES provides seminars, short courses and projects for North Carolina industries to assist them in better utilising manufacturing engineering technologies. The Service has a staff of approximately 20 professionals that provide technical information, applied research on a co-operative basis with industry, and other funded extension projects.

IES provides short courses on a demand basis in the following technologies:

- Electrical and Electronics;
- Manufacturing and Production (MRP II, JIT);
- Maintenance Operations;
- Computer and Automation (CAD/CAM/CIM);
- Industrial Engineering (TQM/TQC);
- Management; and
- Metals and Materials.

Seminars are also available on the above topics.

TEACHING APPROACH

Courses are provided in community colleges, or in some cases, the service offers on-site training at no cost, as part of a concerted program to attract industry to North Carolina. The IES also conducts development projects with local industry. The most common are projects using the IES approach to quick change production. The objective of such projects is to develop methods to accomplish faster set-up times in manufacturing operations and thus to increase overall productivity.

INTERACTION WITH INDUSTRY

The IES is dedicated to linking business, industry and government with the University. Thus, its focus is on consultation rather than on research and development projects. The emphasis on services to industry is similar to the National Industry Extension Service 'NIES' in Australia.

Case Study: NGEE ANN POLYTECHNIC - SINGAPORE

Ngee Ann Polytechnic was established in 1963, and underwent a major expansion in 1986. The Polytechnic is now mostly housed in large modern buildings within one large campus. It has very good student facilities.

It mainly offers courses below degree level in engineering and commerce. It is supported by the Singapore Ministry of Education and in 1988 had approximately 10 500 students and 600 academic staff. In teaching approach and many other respects, the Ngee Ann Polytechnic is comparable to Australian Institutes of Technology.

The Department of Mechanical Engineering (amalgamated with the Department of Electronic Engineering in 1989) offers three main types of course:

- Diploma in Mechanical Engineering (2 or 3 years full-time);
- Advanced Diploma in Mechanical Engineering (2 years part-time); and
- Short courses in mechanical/manufacturing engineering e.g. PLC (60 hours each - evenings).

The two courses are fully funded by student fees while the Diploma is funded by the Ministry of Finance at the rate of $5 500 per student per year.

The Diploma in Mechanical Engineering is 3 years full-time for students entering from school with 'O' level passes and is 2 years full-time for students entering with 'A' level passes. In the final year students are offered a choice of five options:

(a) Plant Design and Maintenance Technology;

(b) Refrigeration and Air conditioning Technology;

(c) Fabrication Technology;

(d) Manufacturing Technology; and

(e) Industrial Automation Technology.

In 1990 the course structure will be changed to give just three options in the final year:

- robotics;
- CNC;
- factory automation systems.

An outline of the present Diploma course is given in Appendix D.

CAD/CAM equipment includes:

- APOLLO and HP work stations;
- 5080 work stations on an IBM Mainframe;
- CATIA software and CADAM software.

In 1989 a Flexible Manufacturing System comprising the following equipment was established for student projects and research:

- Robot Cell 1: comprising a CNC lathe, CNC mill and ASEA robot;
- CNC lathe and machining centre serviced by a robot master;
- auto store;

- storage conveyor;
- Robot Cell 2: Comprises a robot, deburring station, polishing station, autoguaging station and assembly station;
- AGV;
- vision system.

The Department of Mechanical Engineering appears to be strong in research and development of CAD/CAM systems. The Department offers consulting services to industry but this is not a large component of its work. It is developing a significant amount of CAL (computer aided learning) material for use in the Diploma classes. Some of this material may be of use to TAFE colleges in Australia.

Case Study: COVENTRY POLYTECHNIC - MANUFACTURING SYSTEMS ENGINEERING SECTION

Coventry Polytechnic, located in Coventry in the West Midlands of England, has approximately 5 000 students. The School of Mechanical and Manufacturing Systems Engineering was formed by merging the former Departments of Mechanical Engineering and Production Engineering within the Polytechnic. Dr Colin Page and Dr Stuart Spraggett of the Manufacturing Systems Engineering Section of the school were interviewed for this study.

The manufacturing systems engineering courses have a high reputation in industry with Graduates funding jobs in companies throughout Britain. The Manufacturing Systems Engineering Section offers the following courses:

- a Higher National Diploma in Manufacturing Systems Engineering/Production Engineering - 90 students - 2 years full-time (see attached course outline in Appendix D);
- a Bachelor of Engineering Honours degree in Manufacturing Systems Engineering - 120 students - 3 years full-time or 4 years 'sandwich' course of study with industry attachment (see course outline in Appendix D);
- a Master of Science degree in Advanced Manufacturing Technology;
- a Master of Science degree in Engineering Management.

The courses in manufacturing systems engineering at Coventry are intended for engineering diploma and degree level course designers. The diploma and degree level courses were formerly entitled 'production engineering', but have been renamed to reflect the emphasis on management and business studies. The courses have three major components:

- engineering;
- business; and
- management.

There is no flexibility within the degree or diploma course, as no options are offered. However, there is good articulation between the diploma and degree course. Students can and often do transfer from the diploma to the degree with substantial credit allowed.

The ability of students to cross traditional discipline boundaries is seen as an important outcome of the courses. This is fostered in two ways:

- by having a broad-based course; and
- by development of problem-solving skills through project work.

In the degree course, for example, the students undertake three major projects as follows:

- in the second year a multi-component product is designed and a manufacturing system for producing that product is also designed. This 'integrative problem solving assignment' involves about four weeks work for a small team of students spread over a 6 month period;
- in the final year a specific manufacturing project is assigned to individual students. Sometimes real problems from industry are used. This assignment involves about 6 weeks of work spread over a 6 month period;
- also in the final year a major project simulating the launch of a manufacturing company is assigned to a team of about ten students. This involves product design, market research, manufacturing system design, and setting up a company. The outcomes are presented by each student to an audience consisting of school

staff and industry representatives. The project requires at least 6 weeks work by the team, spread over a 6 month period.

Improved access to the degree course is regarded as important by the staff. The traditional requirement for 'A' level mathematics for entry to engineering degree courses, for example, is likely to be relaxed at Coventry because of the need for engineering graduates by industry from a diminishing pool of 'A' level students, the rationale being that much of the 'A' level mathematics is irrelevant to the manufacturing systems engineering course.

A possible future development may involve the merging of the mechanical engineering degree with the manufacturing systems engineering degree so that there is a common first year with divergence thereafter. Another development is the increasing use of self-learning rather than teaching in the engineering courses at Coventry.

Course development is based on staff perceptions of industry's needs. It is important to note that the Polytechnic serves industry throughout Britain - not just the local manufacturers. Staff keep up-to-date through the usual avenues (e.g. journals, conferences) and have informal links with industry. Some consulting work for local companies is conducted, and short courses for particular companies are occasionally mounted. Such fee-for-service courses are expected to greatly increase with the move towards 'privatisation' of polytechnics.

Case Study: GERMAN-SINGAPORE INSTITUTE

The German-Singapore Institute (GSI) was established in 1983 by the Economic Development Board of Singapore through the financial and technical support of the German Agency for Technical Co-operation and various West German manufacturers.

The Institute has a total of 75 staff and 480 full-time students undertaking the Diploma in Production Engineering. In addition to the Diploma, a range of other courses is offered, and are described later in the case study. The recurrent funding of GSI is $S5 million per year and is provided by the Economic Development Board (EDB) of Singapore.

Key features of the GSI are:

- very close links with industry;
- a focus on project work with students working in teams;
- an emphasis on practical learning in a simulated factory environment.

INTEGRATED MANUFACTURING EQUIPMENT - TECHNICAL LABORATORIES

The German-Singapore Institute has a layout similar to a modern manufacturing company, with production areas and technical laboratories. There are very few theory classrooms. The workshops and laboratories include:

- production planning and control workshops for metal machining and plastics technology;
- laboratories for quality control and materials testing;
- workshops for tool and die fabrication and heat treatment;
- robotics, automated assembly and materials handling/management laboratories.

The GSI has a range of CAD/CAM/CAE hardware and accompanying software, and includes:

- 15 computer vision INSTAVIEW work stations on CDS4000/Designer VX systems;
- 34 HP9000 series work stations with networking capabilities;
- a range of terminals including, IBM CP AT, Philips P3200, NEC APC IV and COMPAQ 386 PCs;
- computer vision software (CADDS 4X, personal designer, personal and machinist);
- Hewlett-Packard software (ME10, EGS, HP NC, AC, circuit analysis and wave-form analysis).

CURRICULA

The Institute offers a two year full-time Diploma in Production Engineering (see Appendix D). The course can be divided into two streams; production technology and industrial automation. Entry into the first stream is restricted to 'A' level students only. Electives may also be taken for both streams in the areas of:

- cutting technology and CNC techniques;
- design (tool, die/jigs and fixtures);
- industrial automation; and
- plastics technology.

In the final semester of the Diploma course, a project of between 3 and 6 months duration depending on what stream they are enrolled in is undertaken by students.

These projects, many of which are sponsored by local industries, are instrumental in assessing the students' ability to apply and integrate the knowledge they have learnt, and for gaining relevant industrial experience.

For most projects, the students are involved in the following activities:

- planning and design;
- sourcing and procuring of materials;
- fabrication and assembling; and
- troubleshooting and commissioning.

Other courses offered by the GSI include:

- a one-year advanced course for graduates of the Production Engineering Diploma;
- ad hoc short courses tailored for industry;
- train-the-trainer courses and workshops.

TEACHING APPROACH

There is a marked emphasis on practical work in the courses offered by GSI. After initial theory classes in the early part of the Diploma course, practical classes in a factory production environment predominate. Students entering from school with 'A' level passes especially, start with a heavy emphasis on practical work. This follows through into the project work, where students are required to simulate industrial requirements such as budget and time constraints.

Microcomputer-based project management software is used to help students to plan and monitor their progress. Finally, team work is encouraged in the project phase of the Diploma.

LINKS WITH INDUSTRY

GSI has developed close links with Singaporean industry by offering consultation in its areas of expertise. GSI also undertakes specific projects at the request of industry. Most of these projects form part of the final year of the Diploma course. A team of students is assigned to the project and the team prepares a report of the outcomes. Larger projects likely to require more than three months to complete are undertaken by the Industrial Project Group (IPG). Such projects are undertaken by IPG technical staff, students and lecturing staff.

Each company requesting a project is asked to:

- pay for all hardware and material costs;
- appoint a co-ordinator within the company; and
- pay a small additional fee.

In addition to the Industrial Project Group, the Applied Technology Group (ATG), which operates from both the German-Singapore Institute and the associated Precision Engineering Institute (PEI), helps local manufacturers adopt advanced manufacturing techniques and technologies. Facilities available through the PEI include:

- 160 CAD/CAM/CAE work stations;

- 30 industrial robots; and
- 30 CNC machines.

A more detailed description of the German-Singapore Institute, its courses, equipment, teaching approach and links with industry is given in Appendix C.

Case Study: CIMM CENTRE - REGENCY PARK, SA

The CIMM Centre is located on the Regency College of TAFE campus, approximately 10 kilometres northwest of the Adelaide CBD. Established in 1974, the College caters for over 8 300 students. The College is managed by an executive and is composed of five teaching schools:

- Mechanical Engineering;
- Electrical Engineering;
- Electronic Engineering;
- Plumbing and Sheetmetal Work; and
- Hotel School.

Regency College primarily offers certificate, associate diplomas and diploma level courses for occupations ranging from trade to para-professional.

The School of Mechanical Engineering provides associate diploma, certificate and advanced certificate courses in:

- computer-integrated manufacture (CIM);
- fluid power;
- plant engineering;
- design drafting; and
- plastics processes.

All courses emphasize the use of computer-based technologies to a significant degree. An outline of two present Associate Diplomas in Mechanical Engineering is provided in Appendix D, as they are appropriate to this case study.

INTEGRATED MANUFACTURING LABORATORY - TECHNICAL EQUIPMENT

The School of Mechanical Engineering in association with ATEC (Advanced Technology Education Centre) provides an extensive range of Computer Integrated Manufacturing and Management (CIMM) facilities that include:

- IBM 4361 mainframe computers;
- CADAM 2D and 3D CAD software;
- IBM RT 32-bit work station with CATIA CAD/CAM hardware/software;
- DEC VAX 3500 32-bit work station with CALM and Unigraphics, and ICEM CAD/CAM software;
- Control Data 32-bit work station with ICEM CAD/CAM software;
- a range of MICRO CAD software;
- a range of graphic animation, simulation programs, database management, and manufacture system software;
- Flexible automation systems (CNC Mills, Lathe, Drill and Robotic Systems) with DNC links to ATEC Network;
- Extensive networking facilities and options; NFS facilities etc. including TCIP with links to SAMnet, via SACFM to SAIT, Adelaide University etc.; and

- a range of printers including HP Paintjet colour printer.

LINKS WITH INDUSTRY

Many of these facilities are a result of several joint ventures, the most noteworthy being IBM's participation from 1984 with the School of Mechanical Engineering and ATEC. IBM provided a mainframe computer, numerous CAD terminals and supporting CATIA software which allowed training in a number of related disciplines, namely design engineering, manufacturing, materials handling, shop floor control, office, accounting and expert systems.

The arrangement allows both IBM and Regency College to maximise use of available facilities. Regency College staff can deliver specialised CIMM training to industry clientele, while the College incorporates the advanced computer technology into its vocational education programs. Similar arrangements exist with other computing and software firms, such as Control Data and the Caddsman Pty Ltd, and through the Centre, close links between the College and industry presently exist. Specially tailored courses have been provided to large internationally-based companies such as Mitsubishi Motors, and government authorities, an example being an 18-week course for the South Australian Gas Company (SAGASCO).

TEACHING APPROACH

Integration is an important element of the Centre's philosophy, and is emphasized in diverse activities. The link between concept design, graphic visualisation, and computer aided manufacturing, is evidenced in both the Summer School of Art and Technology conducted for the Australian Network of Art and Technology, and in courses conducted for Adelaide University in their undergraduate programs.

The CIMM Centre operates workshops and seminars on subjects relevant to industry, especially CAD/CAM/CIM, and provides individual 'fee-for-service' programs to other educational or professional organisations. This 'cutting edge' technology is theoretically available to students and industrial groups 24 hours-a-day. ATEC and IBM plan to develop and market Business Planning and Control and other expert systems in the near future as part of Regency College's entrepreneurial venture.

Associated with the CIMM Centre, is the commercially operated CADDSMAN Bureau. Run as a corporate company, CADDSMAN Ltd provides facilities for student or corporate activity. The head office is located on the Regency campus. Operated as a profit-seeking endeavour, its services include: contract work, sale and hire of hardware, software and peripherals, training, consultancy and demonstrations. The company's location has brought mutual benefit to Regency College and CADDSMAN, who share facilities and staff.

Key features of the CIMM Centre that have enabled it to provide training in up-to-date manufacturing technology are:

- a good range of up-to-date computer hardware and software, with a focus on CAD/CAM, through agreements with suppliers such as IBM;
- a large amount of staff development for lecturing staff to keep up-to-date with current manufacturing technology;
- close links with industry through technical projects, seminars and courses.

COMPETITIVE STRATEGY - STAFF DEVELOPMENT

The CIMM Centre believes the success of its operation is due to five major factors:

- Strong links with industry. Staff at the Centre conduct developmental and contracted work which allows 'hands-on-time' which historically TAFE has not been able to provide. This has had a flow-on effect to its students who are predominantly from industry;

- The activities of the Centre are strongly supported by management. Staff are given the opportunity to attend and participate in interstate and overseas training programs and staff exchange with other CIMM establishments is actively encouraged;

- The considerable involvement with equipment supplier training and its associated equipment benefits has given the Centre a competitive edge. Strong 'collegiate' support has been given by leading companies including: IBM, Control Data and Miden Pacific;

- Support from organisations, such as ACADS and the Society for Manufacturing Engineers (SME) in participating in joint seminar presentations with the CIMM Centre has been a major factor in its success; and finally

- Links with the technology transfer agencies such as the South Australian Centre for Manufacturing and the School of the Future are a few of the co-operative ventures presently in train.

Case Study: OAKLAND COMMUNITY COLLEGE - Detroit, USA

Oakland Community College (OCC), is a community college in the USA with an enrolment of 27 000 students. OCC serves the heavily industrialized Detroit community, with its auto makers and many suppliers who are in the forefront of the push towards Computer Integrated Manufacturing. The Auburn Hills campus of the College close to the northern perimeter of Detroit, has a High Technology Centre providing a range of CIM and CIM related courses.

The High Technology Centre is very well equipped with advanced hardware and software mainly due to major partnerships between the College and three companies:

- IBM;
- Cross & Trecker (machine manufacturer);
- Kennametal (tooling manufacturer).

IBM donated both equipment and expertise including computer systems, application software, terminals, a robotics system and the services of a project team over a three-year period. Cross & Trecker designed and equipped the flexible manufacturing work cell at a substantial price discount and are providing equipment upgrades and on-site engineering aid over a three-year period. Kennametal are providing the tooling for this system, along with engineering support. In addition to classrooms and lecture halls, the High Technology Centre houses a Computer Aided Design Laboratory, a CIM Applications Laboratory, a Robotics Laboratory and a Flexible Manufacturing Systems Laboratory. These labs are equipped with 18 IBM engineering graphics work stations, using CADAM, CATIA, AUTOCAD, IBM CAD, AUTOCAM and simulation software, plus sixteen industrial PCs, all for student use.

The Centre's CIM Work Cell is a state-of-the-art Flexible Manufacturing System with a machining centre, turning centre, and robots, all operated with numerical control systems. The computer room contains a newly installed IBM 4361 system, in addition to the 4341 system that the College uses for CAD/CAM instruction. The entire High Technology Centre is fully wired for interactive computer communications in a networking environment.

The College offers five applied science associate degrees in the manufacturing engineering field:

- CIM;
- CAD;
- CNC;
- robotics;
- hydraulics.

Each associate degree requires about two and a half years full-time study. Many of the subjects are common to two or more of the associate degree courses. About 2 000 students are enrolled in the five associate degrees at the College.

In addition to the associate degrees, the College offers nine 'credit courses'. These short courses stand alone but also give credit towards an associate degree. The college also conducts a wide range of non-credit short courses at the request of individual companies. At other campuses the College also offers apprentice programs.

The CIM associate degree offers students both theoretical education and hands-on training in the total CIM concept and in many of CIM's technological components. Students are introduced to CIM through a program which focuses on the goals of CIM - total enterprise integration and, ultimately, manufacturing competitiveness. The major course work in the CIM associate degree includes:

- Introduction to Computer Integrated Manufacturing
- Manufacturing Resource Planning (MRP 11)
- Plant Operation Networking
- Machine Tool Communications
- Introduction to Flexible Manufacturing Systems (FMS)
- FMS Applications.

Other subjects in the course include 'direct support courses' such as CAD, robotics and CNC; 'skill foundation courses' such as electrical, electronics, microprocessors, manufacturing and technical drawing; and 'educational foundations' such as mathematics, English and interpersonal communications. It is significant that interpersonal communication and English are included in the highly technical CIM associate degree. Details of the course are given in Appendix D.

The major coursework involves the student undertaking large practical projects which integrate knowledge and skills acquired in previous subjects. For example, the Flexible Manufacturing Systems subject requires each student to fully design a product, and then process the project from the work shop floor through to completion.

CHAPTER 6: SKILLS REQUIRED

Integrated manufacturing will require a higher level of skill and different types of skills for its operation. Its introduction into the manufacturing sector will affect the workforce - qualitatively and quantitatively, as it involves a reorganisation of the entire manufacturing process. The highly automated and computer integrated manufacturing and production techniques have the potential to bring remarkable improvements in quality and flexibility. The widespread introduction of integrated manufacturing will result in large segments of the labour force requiring extensive training or retraining in computer related skills' (Gordon & Kimball 1985, p.316).

The application of integrated manufacturing can generate both new jobs and at the same time eliminate and restructure existing jobs. Literature reviewed in this project (Hayton & Harun, 1988) revealed that integrated manufacturing will have important training implications. Some of the skills required by the introduction of integrated manufacturing as revealed by the literature and the case studies are discussed below.

NEED FOR CROSS-DISCIPLINARY SKILLS

The introduction of integrated manufacturing will change the skill requirements in the manufacturing sector. The literature demonstrates that there is a need for training for a broader range of skills, as integrated manufacturing is essentially a cross-disciplinary field. Highly specialised and narrowly-defined work tasks will be replaced by 'so-called flow-oriented work organisations where work is more broadly defined and carried out by teams of workers having multi-disciplinary skills' (Economic Commission for Europe 1986, p.134).

This has been borne out by several of the case-studies. Practical training at Sigma Air conditioning emphasised multi-skilling, whereby operators are being trained to perform multiple functions in two or more fabrication and assembly areas within the factory. Philips in Cambridge (UK), encourage increased employee flexibility as part of their human resource strategy. This is especially apparent at the technician level, where willingness to actively broaden skills is seen as the key to success within the company. Similarly, engineers and professional level employees are required to broaden their skills base by obtaining cross-functional work experience.

Cross-skilling is an important facet of Milford's integrated manufacturing strategy. This is achieved through outside training and moving operators between work centres to upgrade skills. This occurs at all levels of responsibility from operator to supervisor.

NEED FOR A HIGHER LEVEL OF SKILL

Most of the authors in the literature surveyed in Hayton and Harun (1988) tended to agree that integrated manufacturing will require higher levels of skill for many of the jobs. It is a highly technology-intensive activity and will demand a workforce with an advanced skill level for its installation, operation, programming and maintenance. The integrated manufacturing process will be highly automated, and in order to achieve maximum efficiency, it will be designed for a substantial degree of process integration and production continuity. These systems require an increased level of maintenance expertise than previously.

Integrated manufacturing will also require workers who are familiar with sophisticated testing tools, instruments and equipment that are necessary for its application.

Given this situation, there is a need for a comprehensive effort to train and retrain to a higher skill level and to realise the significance and importance of diagnosis and maintenance.

The adoption of 'higher level skills' by all employees was seen as crucial to the success of integrated manufacturing in all of the case studies undertaken of manufacturing companies. Operators are being given more responsibilities by managers to control their production and monitor quality; also managers need an understanding of integrated manufacturing technologies and strategic planning.

At Sigma and Bridges, the need for practical skills in MRP-II, CAD, CAM and CNC was critical to the competitive strategies of the respective companies. At Sigma, a 'top-down' sequence was used, where management were first trained in the philosophies and techniques associated with integrated manufacturing, then later, the supervisory staff. Technical staff and operators received specific training in the previously mentioned techniques as required. At Bridges, the ability to use a range of numerically controlled machines was emphasised for non-trade through to technical staff. Basic troubleshooting skills are required for operatives in this company.

Operatives at Milford are required to undertake training in: CNC machining, aspects of CIM and CAD/CAM. Similarly, all employees are expected to be able to carry out basic fault diagnosis. Milford recruit qualified tradespeople or take on apprentices having a minimum education of full high school graduation. All operatives at Milford must demonstrate reading skills and understand technical equipment manuals.

THE IMPORTANCE OF COGNITIVE SKILLS

Integrated manufacturing will bring changes in skill requirements, both in existing work and in new jobs that will be created. There will be an increase in importance of cognitive skill as compared to psycho-motor skill - a shift from manual to mental work (Miller 1986).

Cognitive skills acquisition occurs at all levels at Philips (Cambridge). Training in this area at the operative level involves:

- first line maintenance;
- quality improvement; and
- bottleneck management and process control.

These skills are of course learnt in conjunction with normal operational and procedural training. More advanced training in the above skills are also made available to supervisory and managerial staff.

Philips at Eindhoven encourages technical staff to further develop cognitive skills. These skills lie in areas such as:

- project management;
- design for assembly (DFA); and
- failure mode and effects analysis (FMEA).

THE IMPORTANCE OF AFFECTIVE SKILLS

The introduction of integrated manufacturing requires a general acceptance of the need for change by management and the workforce at both industry and plant level, (Curtain 1988a, p.4-6; DIR 1988, p.17). The significant change in attitudes required at the plant level is described by some authors as a change in the 'culture' of the plant. The culture of a plant is a pattern of beliefs about what is right, important, or acceptable, shared by the people who work there (Manufacturing Studies Board 1986, p.21).

An important issue discussed in the literature is that of *control*, and this is closely related to management and workforce attitudes. Shaiken et al. (1986) concluded from case studies of US manufacturing firms in the early 1980s that programmable technology and flexible manufacturing systems were being introduced in a way that tended to increase production control by senior management rather than increase control at the shop floor level. Fully integrated manufacturing requires some control over production to effect the successful change from senior and middle management to the shop floor. However, before work organisation can be changed in this way, management must be prepared to relinquish some control over production, and operators must be prepared to accept more control.

Sigma appeared to be closely in tune with this aspect of integrated manufacturing skills development. All employees (operators included) were directly involved in discussions on the importance of accurately documenting activities and occurrences at the shop floor level. Operators at Sigma, although not having significant control over actual production processes, are expected to monitor their own performance.

Non-trade staff at Bridges Corporation are expected to engage in quality control activities. Operatives at Philips (in both Eindhoven and Cambridge plants) are encouraged to join 'Quality Circles' to advise management on production problems. Corrective action teams have also been established at the Cambridge plant and involve various departments. Their major task is to deal effectively with specific problems related to production procedures.

Milford has a reasonably skilled shop floor workforce. Some measure of control has been relinquished by middle management, since most operatives have at least a trade certificate background. Individual operators are encouraged to seek training to allow them to carry out basic machine repairs and troubleshooting activities.

THE IMPORTANCE OF COMMUNICATION SKILLS

The ability to effectively communicate with co-workers and employees with different trade and educational backgrounds was seen as a very important part of the human resource training needs of every company studied.

At Sigma, interpersonal communication is being imposed by the establishment of cross-functional teams. Bridges Corporation believe that a high level of communication skills is a requirement for employees above trades level. Philips (Eindhoven) see communication as a major training need for both professional and managerial staff. At the Cambridge plant, operators are selected partially on their ability to communicate and their social/team skills. Operatives at Milford are sent to the local community college to participate in communications training.

LABOUR WITH A HIGHER EDUCATIONAL LEVEL

The introduction of integrated manufacturing will encourage a change in the educational level of the operational workforce. Better working environments may encourage people with a higher educational level to seek jobs in the manufacturing sector. There are therefore implications for selection and placement procedures for training institutions. The design of training programs and determination of training standards will also be affected.

Senior managers of manufacturing organisations will require a high educational level with an understanding of engineering, technology, research and development, design, strategic planning and management concepts for integrated manufacturing.

Technical staff and middle managers will require a wide range of technical and interpersonal skills. Educational qualifications such as associate diplomas should not only provide the skills needed, but also an intellectual base for future adaptation to technological change and further studies.

CHAPTER 7: TRAINING RESPONSES

The introduction of integrated manufacturing will have the effect of greatly increasing the demand for training, and will pose implications for vocational education course content and structure.

Courses preparing individuals for integrated manufacturing (involving, as discussed in earlier chapters; higher skill levels, new technology and integrated work organisation) will need to develop the individual's abilities to:

- adapt to changes in technology;
- more readily transfer skills to new areas of specialisation;
- combine skills in two or more disciplines;
- readily accept and seek retraining at appropriate points throughout working life;
- pass on knowledge to others; and
- appreciate business competencies.

INCREASED DEMAND FOR TRAINING

All the case studies asserted that the demand for training had increased greatly as a result of the introduction of integrated manufacturing. Frequently, the companies stated that the crucial need was to provide training not only in the *technical* aspect of integrated manufacturing techniques, but in the *philosophical* and social framework of integrated manufacturing. Sigma and Bridges especially saw the need for operator level employees to understand the importance of integrated manufacturing to the company's competitiveness.

Most companies took a traditional top-down approach to training for integrated manufacturing with the training beginning with management and eventually filtering down to the shop floor. The need to initiate training at the operator level (where we suggest the greatest potential demand lies) will become increasingly necessary. In short then, training for integrated manufacturing must occur at <u>all</u> levels.

THE TYPE OF TRAINING REQUIRED

The type of training required is changing in many ways. The 'old model' of work and training involved an initial intensive once-only training program (e.g. an apprenticeship with TAFE trade training) followed by full-time work with little or no formal training for the remainder of the person's career. The 'new model' involves intermittent or continuing education and training throughout the person's working career. More intensive initial training will still be required in most cases.

Initial vocational education and training should provide the broad knowledge of the industry and a good foundation for further training. It is widely acknowledged that initial vocational training should involve the development of both general skills (such as mathematics, science, interpersonal communication, quality improvement, and safety) and specific vocational skills.

TAFE will need to address the need for continuing retraining possibly by the greater provision of individually designed short courses or modules to meet the specific training needs of industry. These short courses or modules could be designed to form part of a larger course structure.

It is generally agreed that there is a need for industry in Australia to make a higher level of commitment to training (Hall 1987; 1988; Dawkins 1988). This need may be partly met by TAFE and other training providers offering modules from larger accredited courses. To meet the range of needs of people in the workforce, flexibility in course provision is required. Two types of retraining may be distinguished;

- courses which 'update' skills in cases where new technology is being introduced; and
- courses which provide additional skills in a new area (including 'multi-skilling').

Both types of retraining will be essential for integrated manufacturing. Short courses designed for industry are features of the educational case studies discussed in Chapter 5.

The Lehigh University CIM Laboratory offers short courses in specific integrated manufacturing topics including; JIT, MRP II, FMS and TQC. The Industry Extension Service (IES) at North Carolina State University, and the Oakland Community College in Detroit, also provide industry liaison and courses in much the same format as Lehigh. The courses offer considerable flexibility and are frequently offered to companies on site.

The keyword for appropriate course structures of the future is flexibility, and it has been suggested that this could be achieved more readily by a modular course structure with broad-based modules early in the course. (Hayton 1986, p.140; Hall & Hayton 1988, p.7). Each module should be able to stand alone and be capable of being assessed separately. However, some modules will need to specify pre-requisite skills or modules. The structure should allow for multi-skilling, multiple-entry and exit-points, and retraining.

This flexibility is enhanced if:

- the length of the course (or period of study) is not considered a major criterion of learning success;
- courses specify the competency standards to be achieved and the conditions under which the competencies are to be achieved (DOLAC 1988); and
- courses can be developed, approved, accredited and reaccredited quickly.

None of the educational institutions discussed in Chapter 5 offered flexible course structures in the traditional sense of the term. In several, there appeared to be good articulation between courses, especially at the Oakland Community College, the Lehigh University CIM Laboratory and the Industry Extension Service. These institutions offered various short courses aimed specifically at industry and which could be tailored to a company's needs.

CONTENT OF COURSES OR MODULES

The case studies reveal two essential features of course content needed to support integrated manufacturing:

- interpersonal skills development is very important for all in the workplace;
- a very wide range of technical skills is required by the workforce.

The first may surprise some but the need for good interpersonal skills emerged as essential from all the case studies of manufacturers. These skills included:

- communication skills, including face-to-face communication, document and report-writing skills;
- team skills, including co-operation, team management, learning and teaching skills.

For example, the management of Philips in Cambridge views communication and

team/social skills as very important for operators, and provides a two-day residential course on basic communication to be undertaken by all operators.

Technical skills required for integrated manufacturing identified in the case studies ranged from general skills, such as understanding the company's competitive strategy to specific skills such as bottleneck management. Some of the skills required could be similar even for manufacturers not implementing an integrated manufacturing strategy.

Skills required by operators (and first-line supervisors) include knowledge of:

- key parts of the company's competitive strategy;
- the philosophy underlying integrated manufacturing;
- quality control and quality improvement principles and practices;
- safety issues;
- CNC machine operation;
- FMS;
- OPT;
- first-line maintenance; and
- bottleneck management.

Skills required by technical staff (including tradespeople) include knowledge of:

- CIM
- DFA
- CAD
- CAM
- Quality Management
- CNC
- JIT
- electronics
- project management
- MRP-II; and
- advanced production and inventory control systems.

Skills required by management for integrated manufacturing include knowledge of:

- strategic planning;
- integrated manufacturing philosophy;
- work organisation/production cells;
- MRP-II;
- CAD; and
- CAM.

Many of those interviewed in manufacturing companies and educational institutions commented on the need for skills to support technological and work organisation change. The introduction of integrated manufacturing requires more than technical skills and interpersonal skills : it requires confidence, acceptance of change, an understanding of manufacturing strategy, and skills in managing the change. Such skills are often discussed in the context of 'cultural changes' required within the manufacturing organisation. Bolwijn and Kumpe (1988) refer to the 'culture' of the four organisational phases (see Chapter 3).

Educational institutions such as the Melbourne Graduate School of Management and Regency College of TAFE believe that an important way of developing these required skills is by presenting real case studies and by discussion of personal experiences of students involved in technological change in their workplace.

Outlines of the content of five exemplary integrated manufacturing courses are presented in Appendix D.

JOINT VENTURES WITH INDUSTRY

Several joint ventures between educational institutions and industry featured in the case studies of Chapter 5. Generally, these took the form of high technology machinery

suppliers donating specific equipment to CIM laboratories located within education institutions in return for the delivery of specialised CIM training to their industry clients. Other links with industry related to technology transfer between institution and industry and project work on a contractual basis.

The Lehigh University CIM Laboratory carried out specifically tailored project research, seminars and courses, directly funded by industry grants and having a dual benefit. Individual participating companies benefit by receiving specific project research and input into the Laboratory's activities, while the University is given the opportunity to upgrade its CIM systems. A similar situation also exists at CMSE and the Intelligent Systems Laboratory. Emphasis in the United States has been placed on applied research with considerable liaison between education and industry.

Other institutions, such as the Coventry Polytechnic exhibit a more informal link with industry. Occasional consulting and fee-for-service courses have been provided to specific companies; however, with the move toward privatisation, consultative activities are expected to increase to make their facilities commercially viable. The German-Singapore Institute has also developed close links with industry in much the same manner as demonstrated in the US case studies. Technology transfer, industry project work and courses are a feature.

The CIM Centre in South Australia has very strong links with industry through its industrial CIMM training programs, its links with high technology suppliers like IBM and its consulting activities, both locally, interstate and overseas.

The role of educational institutions in providing technical expertise and training to industry is greatly increasing, and will continue as the need to improve the competitive status of manufacturing industry becomes crucial.

TECHNICAL EQUIPMENT

The educational institutions described as case studies in this project displayed a good range of modern hardware and software for integrated manufacturing. All had CAD/CAM equipment and some had an industrial size flexible manufacturing cell.

An important issue here is the selection of a particular brand or model. Some CAD systems, for example, are considered the 'state of the art' technically but are considered to be less useful for educational purposes. Some educational institutions have had sufficient resources to buy both types of systems:

- one useful educationally, particularly for initial training;
- one technically advanced, for advanced training and for industry consulting work.

Because of the high cost of much of the CAD/CAM and CIM equipment, some educational institutions found it very difficult to provide a good range of modern equipment for their students. In some cases, older and cheaper equipment was used, and sometimes the teaching staff improvised with add-ons or modifications to the older equipment.

Equipment suppliers such as IBM have given substantial support to a small number of selected educational institutions. The consequence is that some colleges are well resourced while others are not. Like the equipment suppliers, TAFE agencies in Australia have had to concentrate resources for modern integrated manufacturing equipment in one or two colleges in each State.

A recent TAFE National Centre report (Baker 1990) advocates the use of physical modelling systems in colleges for the teaching of principles of integrated manufacturing. It is claimed that these offer advantages of:

- greatly reduced cost compared with industrial size systems; and
- significant educational benefits in terms of ability to generalise concepts across different systems and different industries.

Even in educational institutions where industrial size systems are available, physical modelling systems should be considered in order to supplement the equipment and to teach more general concepts of manufacturing integration and automation.

TEACHING APPROACH

As part of their teaching approach, most of the educational institutions with CIM laboratories, provide short courses tailored to meet specific industry needs. A feature of these courses are their 'hands-on' orientation. Another feature is the provision of project or research services for, and sponsored by local industry. Two examples, the German-Singapore Institute and the Coventry Polytechnic, are of particular interest.

As part of the Diploma in Production Engineering at the German-Singapore Institute, a project is undertaken by each student, usually as part of a team or group, on an industry-sponsored research project. This has found to be instrumental to the student's ability to integrate and apply learnt knowledge to relevant industrial situations. The company benefits by receiving specific research and input to the Institute's operations.

Coventry Polytechnic takes a different approach. Here, each student is assigned to a project group of approximately ten students. They are required to develop a theoretical company including the product design, market research, manufacturing system design and setting up of the 'company'. In addition to this teamwork project, an industry-type project is completed by individual students.

Similarly, the two American case studies, used industry projects in their teaching approach. Engineering students at both Lehigh and North Carolina State Universities are required to complete an individual project in their final year of study, related to an actual industrial application.

The presentation of case studies and student discussion of personal experiences of technological change are both approaches used by Regency College of TAFE and other institutions to develop skills associated with the 'cultural' change required in manufacturing organisations.

REFERENCES AND FURTHER READING

ACTU/TDC Mission to Western Europe. (1987). *Australia Reconstructed: A report by the Mission Members.* Canberra: AGPS.

Australian Bureau of Statistics. (1989). Catalogue No. 813.0: *Manufacturing Technology Statistics Australia - Summary.* Canberra: ABS.

Australian Bureau of Statistics. (1990). Catalogue No. 5220.0: *National Accounts - Australia.* Canberra: ABS.

Australian Bureau of Statistics. (1990). Catalogue No. 6203.0: *The Labour Force - Australia.* Canberra: ABS.

Australian Bureau of Statistics. (1990). *Yearbook.* Canberra: ABS.

Australian Manufacturing Council. (1988). *Skills for Manufacturing Industry: Future directions.* Canberra: AGPS.

Australian Manufacturing Council. (1990). *The Global Challenge: Australian manufacturing in the 1990's.* Melbourne: Papper, Carter, Evans and Koop (TELESIS).

Argote, L., Goodman, D.S., & Schkade, D. (1983). The human side of robotics: how workers react to robots. *Sloan Management Review,* 24 (3), 31-41.

Atkinson, J. (1984). Manpower strategies for flexible organisations. *Personnel management,* August 28-31.

Atkinson, J. (1980). Unskilled workers suffer effects of technology. *Australian,* November.

Award Restructuring: Resource package for TAFE teachers. (1990). Sydney: NSW Department of TAFE, Department of Industrial Relations, Department of Employment, Education and Training.

Badham, R. & Wilson, S. (1989). *Current training initiatives for integrated manufacturing (IM) in New South Wales, Victoria and South Australia.* Wollongong NSW: Department of Science and Technology Studies, University of Wollongong.

Baker, L. (1988). EDI - the ultimate competitive advantage? *Perspectives - ACI Computer Services,* 1 (4), 6-7.

Bamber, G.J. (1987). Review articles: manufacturing technologies and human resource management. *Prometheus,* 5 (2), 409-417.

Betrand, O. & Noyelle, T. (1988). *Human Resources in Corporate Strategy: Technological change in ranks and insurance companies in five OECD countries, France, Germany, Japan, Sweden and the United States.* Paris: OECD.

Blache, K.M. (1988). *Success Factors for Implementing Change: A manufacturing viewpoint.* Michigan: Society of Manufacturing Engineers.

Bolwijn, P.T., Boorsma, J., van Breukelen, Q.H., Brinkman, S. & Kumpe, T. (1986). *Flexible Manufacturing: Integrated technological and social innovation.* Amsterdam: Elsevier.

Bolwijn, P.T. & Kumpe, T. (1988). *Flexibility, what next..? The industry in the nineties.* Eindhoven: Philips.

Bolwijn, P.T. & Brinkman, S. (1985). *Divide and Control: Japanese factories.* Eindhoven: Philips.

Bolwijn, P.T. & Brinkman, S. (1987). Japanese Manufacturing: Strategy and practice. *Long Range Planning.* 20(1), 25-34.

Boyer, R. (1988). *Is a new socio-technical system emerging? Conference on Structural Change and Labour Market Policy* organised by the Arbetslivscentrum, Var Gard, 6-9 June.

Bright, R. (1981). Does automation raise skill requirements. *Harvard Business Review,* 104, 42-53.

Brodner, P. (1987). Towards an Onthropocentric approach in European manufacturing. *Vocational Training Bulletin,* 1/1987, 30-39.

Bugler, J. (1968). *The maintenance men.* New Society, June 20.

Burgess, C. (1986). *The Impact of New Technology on Skills in Manufacturing and Services.* Sheffield: Manpower Services Commission.

Business Council of Australia, Industrial Relations Study Commission. (1989). *Enterprise-based Bargaining Units: A better way of working. Report to the Business Council of Australia by the Industrial Relations Study Commission.* Melbourne: Business Council of Australia.

Canadian CAD/CAM Council for the Advancement of Computer Integrated Manufacturing. (1986). *Management in Crisis: Implementing computer integrated manufacturing in Canada.* Canada: Minister of Supply and Services.

Child, J. (1984). New technology and development in management organisations. *Omega* 12, (3).

Chown, M. (1985). Productivity begins at school. *New Scientist,* No. 1465, 24-25.

Clark, T.W. (1990). *Getting to Grips with Skills Audits.* Adelaide: TAFE National Centre for Research and Development.

Clayton, J.W. & Fietz, M.E. (1986). DIM - A strategic decision. *Society of Manufacturing Engineers,* 2 (39), 2-50

Cook, J. (1986). Simplifying the factors of the future. *Business Review Weekly,* August 22, 1986.

Craven, F.W. & Slatter, R.R. (1988). An overview of advanced manufacturing technology. *Applied Ergonomics,* 19 (1), 9-16.

Cross, M. (1984). Applying microelectronics to manufacturing, the need for skills. *Management Decision,* 22 (1), 3-9.

Curtain, R. (1987a). Skills enhancement and industry restructuring. *National Economic Review,* No. 7 June 1987, 69-75.

Curtain, R. (1987b). Skill formation and the enterprise. *Labour and Industry.* 1, (1), 8-38.

Curtain, R. (1988a). *Guidelines on career path development and job restructuring: fifteen issues to consider. (Working Paper Series: No.8).* Sydney: Department of Industrial Relations, University of Sydney.

Curtain, R. (1988b). Skill formation in manufacturing: obstacles and opportunities. *Human Resource Management Australia,* November 1988,

Curtain, R. (1990). Sixteen Case Studies of Award Restructuring. Working paper series. Industrial Relations Research Centre, University of NSW, Sydney: National Key Centre in Industrial Relations, Monash University, Melbourne.

Curtain, R. & Mathews, J. (1990). Two models of award restructuring. *Labour and Industry*, 4 (1).

Davis, L. (1985). Automated manufacturing training needs work in computer controlled manufacturing. *Manufacturers Monthly*, November, 1985.

Dawkins, J.S. (1987). *Higher education. A policy discussion paper.* Canberra: AGPS.

Dawkins, J.S. (1988). *Industry Training in Australia: The need for change.* Adelaide, NPITC.

Dawkins, J.W. (1988). *A Changing Workforce.* Canberra: AGPS.

Dawkins, J.S. (1988). *Higher Education: A policy statement.* Canberra: AGPS.

DEET: Department of Employment, Education and Training (in press). *Conducting workforce studies.* Canberra: AGPS.

De Derment, W. (1987). The human element in tomorrow's factory. *Vocational Training Bulletin*, 1 19-23.

Department of Industrial Relations. (1988). *Labour Market Reform: The industrial relations agenda.* Canberra: AGPS.

DITAC: Department of Industry Technology and Commerce (1987a). *Integrated manufacturing: Human resource implications.* Adelaide: Corporate Publishing.

DITAC: Department of Industry Technology and Commerce (1987b). *Integrated Manufacturing: The management challenge.* Adelaide: Corporate Publishing.

DITAC: Department of Industry Technology and Commerce (1988). Advancing Australian Industry. *Report of the proceedings of a workshop on advanced manufacturing technology.* Canberra.

DOLAC: Departments of Labour Advisory Committee. (1988). *A Discussion Paper on Competency-based Trade Training.* Canberra: Department of Employment, Education and Training.

d'Iribarne, A. (1987). New training and new skills in new factories. *Vocational Training Bulletin*, 1 7-12.

Domm, G. (1983). *Flexible Manufacturing Systems: Implications for employment and training in Victoria.* Melbourne: Ministry of Employment and Training.

Dunmaine, B. (1989). *How Managers can succeed through Speed.* Fortune. 13.

Ebel, K.H. (1985). Social and labour implications of flexible manufacturing systems. *International Labour Review*, 124, (2), 133-145.

Ebel, K.H. & Ulrich, E. (1987). Some workplace effects of CAD and CAM. *International Labour Review*, 126, (3) 351-369.

Economic Commission for Europe. (1986). *Recent Trends in Flexible Manufacturing.* New York: United Nations.

Engineering Council (UK). (1983). *Appraising the Technical and Commercial Aspects of a Manufacturing Company.* 2nd ed. London.

Engineering Council (UK). (1988a). *Career Manager.* London: DES/PICKUP in conjunction with the Engineering Council.

Engineering Council (UK). (1988b). *Continuing Education and Training: A national system for engineering: consultative document.* London: DES/PICKUP in conjunction with the Council.

Engineering Council (UK). (1988). *An Integrated Engineering Degree Programme: Consultative document.* London DES/PICKUP in conjunction with the Council.

Engineering Council (UK). (n.d.). *An Integrated Engineering Degree Programme: Guideline syllabuses.* London.

Engineering Council (UK). (1986). *Managing Design for a Competitive Advantage.* London.

Engineering Council (UK). (1983). *Technical Reviews for Manufacturing, Process and Construction Companies.* London.

Engineering Industry Training Board (UK). (1985). *Occupational Profile: Trends in employment and training of technicians in the engineering industry.* Watford: EITB.

Engineering Industry Training Board (UK). (1988). *Occupational Profile: Trends in employment and training of craftsmen and craftswomen in the engineering industry.* Watford: EITB.

Ford, B. (1987a). *Innovative Approaches to Work Learning from Others.* Melbourne: Commission for the Future.

Ford, B. (1987b). Hi-tech lessons from overseas. *Future,* April, 8-15.

Foyster, J. (1990). *Getting to Grips with Competency-based Training and Assessment.* Adelaide: TAFE National Centre for Research and Development.

Franchak, S.J. & Smith, M. (1986). *Preparing for High-technology: Successful co-op strategies.* Ohio: National Centre for Research in Vocational Education.

French, H.W. (1981). *Engineering Technicians - Some problems of Nomenclature and Classification.* Paris: UNESCO.

Fuller, D.E. & Oxley, S.P. (1987). An industry studies framework - methods of assessing industry performance and skill requirements. Paper presented to Canberra CAE, July 1987.

Gardiner, Keith M. (1982). Furthering the integration of manufacturing: the role of a corporate technology institute. Paper presented to the Third National Conference 'Improving the Productivity of Technical Resources' at I.I.T. Research Institute, Chicago, No. 3-4, 1982.

Goldratt & Cox. (1982) *The Goal.* Gower.

Gordon, R. & Kimball, L.M. (1985). High technology, employment and the challenges to education. *Prometheus,* 3, (2) 315-330.

Gough, R. & Stiller, L. (1983). Technology, control, information and work organisation: what are the options? *Work and People,* 9(2), 9-13.

Groover, M.P. & Zimmers, E.W. (1984). *CAD/CAM: Computer aided Design and Manufacturing.* Englewood Cliffs, New Jersey: Prentice-Hall.

Groover, M.P. (1987). *Automation, Production Systems, and Computer Integrated Manufacturing.* Englewood Cliffs, N.J.: Prentice-Hall.

Hadler, R. (1987). Services trades 'a last potential. *Weekend Australian*, December 5-6, 1987, 31.

Hall, W., Hayton, G., Sandery, C. & Davis, R. (1985). *Information Technology Within Tratneeships: Options for TAFE-based courses.* Adelaide: TAFE National Centre for Research and Development.

Hall, W.C. (1987). *The Continuing Education Needs of Academic Staff: Full-time TAFE college lecturers.* Adelaide: TAFE National Centre for Research and Development.

Hall, W.C. (1988). *TAFE/Industry Partnership: Towards more effective relationships in course development and implementation.* Adelaide: TAFE National Centre for Research and Development.

Hall, W.C. & Hayton, G. (1988). *Industry Restructuring and TAFE: A discussion paper.* Adelaide: TAFE National Centre for Research and Development.

Hayes, R.H., Wheelwright, S.C.& Clark, K.B. (1988). *Dynamic Manufacturing.* Free Press.

Hayes, R.H. & Wheelwright, S.C. (1984). *Restoring Our Competitive edge - Competing Through Manufacturing.* New York: Wiley.

Hayton, G. (1986). *Occupational Clusters of the Engineering Technical Workforce.* Adelaide: TAFE National Centre for Research and Development.

Hayton, G. (1988). The translation of labour market needs into training responses. Paper presented at the conference on Australian Skill Shortages and Labour Market Data at the Centre for Research into Education and Work, Macquarie University, 12-13 May.

Hayton, G. & Cheyne, M. (1988). *An Evaluation of Post-trade Courses in Fluid Power Relevant to the National Metal Industries Award.* Adelaide: TAFE National Centre for Research and Development. Sydney: Amalgamated Metal Workers Union.

Hayton, G., Fuller, D., Clark, T., Guthrie, H., & Oxley, S. (1988). *Training for Australian Industry.* Canberra: AGPS.

Hayton, G. (1990). *Getting to Grips with Industry Restructuring.* Adelaide: TAFE National Centre for Research and Development.

Hayton, G. & Harun, M. (1988). *Training for Integrated Manufacturing: A review of recent literature.* Adelaide: TAFE National Centre for Research and Development.

Higgins, P. (1986). Trends in automation and work in manufacturing. *Journal of Occupational Health and Safety - Australia and New Zealand*, 2(1), 33-37.

Hill, S. (1988). Work and technology change in Australia. In Najman, J.M. & Western, J.S. (eds). *A Sociology of Australian Society.* Melbourne: Macmillan.

Hill, T. (1984). *Manufacturing Strategy.* New York: Wiley.

Holland, J.R. (ed.) (1984). *Flexible Manufacturing Systems.*

Integrated Manufacturing Systems Engineering Institute. (1987-1988). *5 Vols. By laws and Agreements; Generic Research Projects 1988; Laboratory Facilities, Graduate Policies and Procedures Manual; Student Research Projects.* 5 v. Raleigh, NC: North Carolina State University.

International Labour Office (ILO). (1979). *Introduction to Work Study.* 3rd rev. ed. Geneva: ILO.

Interstate Commission. (1989). *Interstate Commission Waterfront Investigation: Special studies volume one.* Canberra: AGPS.

Jay, Donald E., Dubensky, R.G. & Salansky, R.K. (1988). *Manufacturing Techniques for Compositive Materials - Current and future automotive trends.* (SEA Technical Paper Series No. 881248).

Jones B. & Scott, P. (1987). Flexible manufacturing systems in Britain and the USA. *New technology, Work and Employment*, 2, (1), 27-36.

Jupiter Consortium. (1987). *Managing Technology*. Uxbridge: The Consortium.

Kaplinsky, R. (1984). *Automation: The technology and society*. London: Longman.

Kern, H. & Schumann, M. (1987). Limits of the division of labour, new production and employment concepts in West German industry. *Economic and Industrial Democracy*, 8, 151-170.

Kleindorfer, P.K. (ed.) (1985). *The Management of Productivity and Technology in Manufacturing*. New York: Plenum Press.

Kohler, C. & Schultz-Wild, R. (1985). Flexible manufacturing systems - manpower problems and policies. *Journal of Manufacturing Systems*, 4, (2), 135-146.

Kumpe, T. (ed.) (1988). *Vertical Integration: A choice between all or nothing*. Eindhoven: Philips.

Kumpe, T. & Bolwijn, P.T. (1988). Manufacturing: the new case for vertical integration. *Harvard Business Review*, 66 (2), 75-81.

Majchrzak, A. (1986). A National Probability Survey on Education and Training for CAD/CAM. Paper from the 1st International Conference in Engineering Management. p.115-121.

Majchrzak, A. (1988). *The Human Side of Factory Automation: Managerial and human resource strategies for making automation succeed.* San Francisco: Jossey-Bass Publishers.

Manufacturing Studies Board (USA) (1986). *Human Resource Practices for Implementing Advanced Manufacturing Technology*. Washington: National Academy Press.

Marceau, J. (1987). Skills, tasks and technologies - the use of human resources in Australian business. Paper presented to the Third Biennial ANU Economic History Conference: The acquisition and utilisation of human resources in Australia. Canberra: Research School of Social Sciences, ANU.

Martin, R. (1987). New jobs for new technology. *Industrial Society Magazine*, September, 1987, 34-35.

Mathews, J. (1988). New production concepts. *Paper presented to the International Workshop on Engineering Design and Manufacturing Management.* University of Melbourne, 22 November.

Mathews, J., Hall, G. & Smith, H. (1987). *Towards Flexible Skill Formation and Technological Literacy: Challenges facing the education system.* Melbourne: Victorian Ministry of Education.

Mathews, J., Hall, G. & Smith, H. (1988). Towards flexible skill formation and technological literacy: Challenges facing the education system. Economic and Industrial Democracy, 9, 497-522.

Matthews, J. (1989). *Tools of Change: New technology and the democratisation of work.* Sydney: Pluto Press.

Matthews, J. (1989). *Award Restructuring: The challenges and opportunities for TAFE.* Melbourne: State Training Board.

McDerment, W. (1987). The human element in tomorrow's factory. *Vocational Training Bulletin*, 1, 19-23.

McFarlane, A. (1988). *Computer Integrated Manufacturing and Management*. Adelaide: School of Mechanical Engineering, Regency College of TAFE.

Menon, U. Cheda, A. & Young, A. (1988). Computer Integrated Manufacturing (CIM). Cal Poly CIM Plan, Nov. 8 1988 (paper)

Meredith, H. (1985). Computers in manufacturing. *Australian*, September 10, 1985, 7-99.

Miller, R.K. (1986). *Strategic Planning for Computer Integrated Manufacturing*. Madison: SEAI Technical Publications.

Miller, S.M. (1985). Impacts of robotics and flexible manufacturing technologies on manufacturing costs and employment. In Kleindurfer P.R. (ed.) (1985). *The Management of Productivity and Technology in Manufacturing*. New York: Phenum Press.

Ming, Yek Tiew (n.d.). Application of CNC Technology in CAD/CAM-CNC System Environment. (paper). Singapore: Ngee Ann Polytechnic.

Mortimer, J. (ed.) (1985). *Integrated Manufacture*. London: IFS Publications.

Murphy, S. (1988). Human centred CIM systems. (paper).

National Training Council. (1984). *Microelectronics training needs report*. Canberra: AGPS.

NEDO: National Economic Development Office. (1985). *Advanced Manufacturing Technology: On engineering batch production*. London: NEDO.

New, C.C. & Sweeney M.T. (1984). Delivery Performance and Throughout Efficiency in UK Manufacturing Industry. *International Journal of Physical Distribution Management*, 14, (7).

Owen, M. & Clark, I. (1988). *Statistics Process Control: A summary*. (Further Education Education Unit/PICKUP Project Report). London: FEU.

Papas Carter Evans & Koop/Telesis. (1989). *What Part will Manufacturing Play in Australia's Future: Interim report of the Pappas Carter Evans & Koop/Telesis study*. Melbourne: Australian Manufacturing Council.

Parkinson, K.J. (1985). *Articulation of TAFE Middle-level and Higher Education Courses*. Adelaide: TAFE National Centre for Research and Development.

Parkinson, K.J. Mitchell, R.S. & McBeath, C. (1986). *Cross-sectoral Transfer from TAFE to Higher Education*. Adelaide: TAFE National Centre for Research and Development.

Philips Radio Communication Systems Ltd., International Production Centre (1988). *Training Guide*. Cambridge: Philips RCS.

Piore, M.J. & Sabel, C.F. (1984). *The Second Industrial Divide: Possibilities for prosperity*. New York: Basic Books.

Riche, R.W. (1982). Impact of a new electronic technology. *Monthly Labour Review*, March 1982, 37-39.

Roberts, E. (1984). The industry/educational partnership for computer integrated manufacturing (CIM). *Society of Manufacturing Engineers, Technical Paper*, MS 4-21.

Rothwell, S. & Davidson, D. (1982/1983). Technological change company personnel policies and skill development. *Journal of General Management*, 8, (2), 87-93.

Rutt, D.P., Minton, G.D., & Copp, D.P. (1986). *Developing a Curriculum for Tomorrow's CIM Manager*. Lake Buena Vista, Fla.: World Conference on Continuing Education.

Samson, D.A. (1990). Achieving competitiveness through 'strategic' operations. Australian Director, Aug. 17-64 (part 1); part 2 unpubl. manus.

Samson, D.A. (1991):(forthcoming). *Manufacturing and Operation Strategy*. Melbourne: Prentice-Hall.

Shaiken, H., Herzenberg, S. & Kuhn, S. (1986). The work process under more flexible production. *Industrial Relations*, 25, (2), 67-183.

SSCIST: Senate Standing Committee on Industry, Science and Technology. (1988). *Manufacturing Industry Revitalisation: Making it together*. Canberra: AGPS.

Stern, D. (1989). Elements of Learning - Intensive Production. (Paper presented to American Educational Research Association, 28/3/89).

Taylor, F.W. (1911). *The Principles of Scientific Management*. New York: Norton.

Thomson, P. (1988). *The School of Hard Knocks: A study on the assessment of experiential learning*. Adelaide: TAFE National Centre for Research and Development.

Tripartite Mission to Japan, Unites States of America, Federal Republic of Germany and Sweden. (1989). The Australian Vehicle Industry. *Meeting the Challenge: What award restructuring really means*. Overseas Mission report summary. Canberra: Dept. of Industrial Relations.

Weisbord, M. (1987). *Productive Workplaces: Organising and managing for dignity, meaning and community*. San Francisco: Jossey-Bass.

Wobbe, W. (1987). Technology, Work and Employment - New trends in the structural change of society. *Vocational Training Bulletin*, 1/1987, 3-6.

Workplace Change. (1989, July) (3). Commonwealth Department of Industrial Relations.

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GLOSSARY OF KEY MANUFACTURING TERMS

ADVANCED MANUFACTURING TECHNOLOGIES (AMT): advanced technologies or management techniques used in manufacturing to increase the efficiency and flexibility of key manufacturing processes.

COMPUTER AIDED DESIGN (CAD): refers to the use of computers for drawing and designing parts or products.

COMPUTER AIDED ENGINEERING (CAE): a computerised technique for testing alternative designs such as for stress and other engineering-related characteristics.

COMPUTER AIDED MANUFACTURING (CAM): refers to the application of programmable computing power to manufacturing processes.

COMPUTER AIDED PRODUCTION (CAP): software that links parts needed with suppliers and inventory in a manufacturing situation.

COMPUTER INTEGRATED MANUFACTURING (CIM): a concept in which all aspects of the manufacturing process are integrated and controlled by a computer system.

COMPUTER NUMERICAL CONTROL (CNC): a process of controlling a machine by transferring a set of digitized instructions from a computer terminal to the execution of a process.

FLEXIBLE MANUFACTURING SYSTEMS (FMS): are approaches to manufacture which involve techniques such as Group Technology and Cellular Manufacturing to provide production of small batches and one-off products with efficiency similar to that of mass production approaches.

INTEGRATED MANUFACTURING (IM): is an approach to manufacturing which aims to improve productivity, quality and flexibility. It involves the integration of all aspects of the organisation's operation including machines, the workforce, systems and procedures through the application of computer technologies and integrated types of work organisation.

JUST-IN-TIME (JIT): a manufacturing approach which improves productivity through a production method based on inventory control. It aims to keep inventories to a minimum by delivering parts 'just-in-time' for their assembly. Also known as the 'Kanban' system. It is a 'pull' system (demand based) involving card requests for replacement parts and materials.

LOCAL AREA NETWORK (LAN): use of local area network to exchange technical data and information between different points on the factory floor or within individual departments.

MANUFACTURING RESOURCES PLANNING (MRP11): a manufacturing approach involving a computer program that identifies the most efficient production plan and inventory levels for all functions in the organisation. It is a 'push' system (supply based) involving monthly orders.

OPTIMISED PRODUCTION TECHNOLOGY (OPT): a proprietary computer package based on production data and facilities available from plant records.

TOTAL QUALITY MANAGEMENT (TQM): an approach which integrates improvement in productivity and quality. It is a 'total' approach and involves all products, processes and people in an organisation dedicated to improvement efforts;.

VALUE-ADDED MANAGEMENT (VAM): an organisational technique which critically evaluates all activities in terms of a value added to a product or service.

GERMAN-SINGAPORE INSTITUTE

While Chapter 5 gives an overview of the German-Singapore Institute, a much more detailed description is provided here for those who require it.

INTRODUCTION

The German-Singapore Institute (GSI) is located at Jurong, about 15 kilometres east of the city of Singapore. It was established in 1983 by the Economic Development Board of Singapore through financial and technical support of the German Agency for Technical Co-operation and West German manufacturers (see Figure 1 for a full list of supporting organisations).

The German-Singapore Institute has a total of 75 staff (about 55 teaching staff), and 480 full-time students undertaking the Diploma in Production Engineering. In addition to the Diploma, a range of other courses is offered, and these courses are described in a subsequent section.

The recurrent funding of GSI is $S5 million per year and this is provided by the Economic Development Board (EDB) of Singapore. In addition, German Singaporean and international companies provide equipment and technical support. The EDB also funds the full-time Diploma students at the rate of $S300 per month.

The key features of the GSI are:

- very close links with industry;
- a focus on project work with students working in teams; and
- an emphasis on practical learning in a simulated factory environment.

The motto of GSI is:

> "We are doing production for learning, a company is doing production for earning."

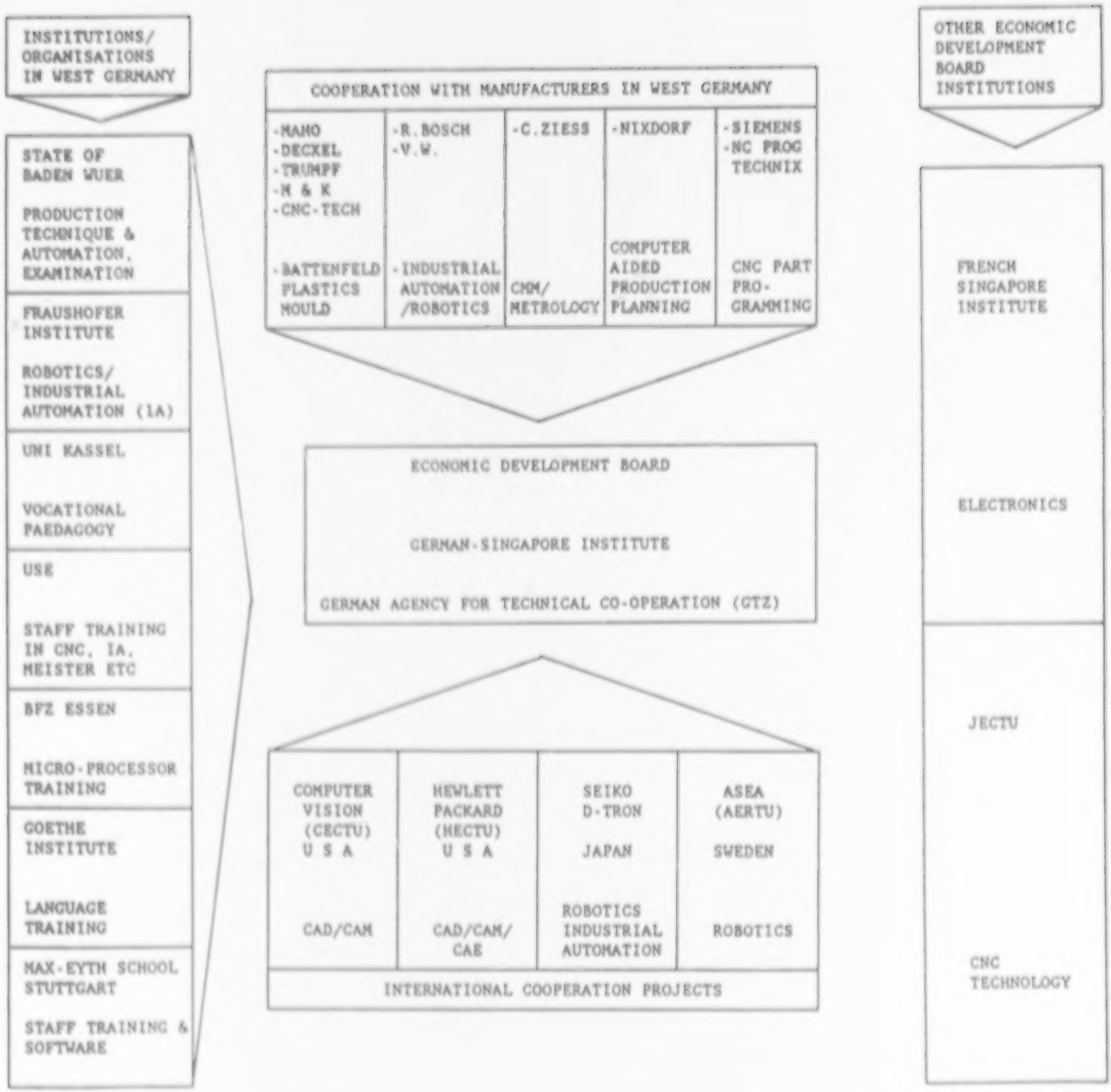


Figure 1: Organisations supporting the German-Singapore Institute

NATIONAL CONTEXT

Singapore has a dual system of government-funded tertiary education: one supported by the Ministry of Education, the other supported by the Economic Development Board (see Figure 2). Both support an overlapping range of courses from trade level to degree, but the course contents and teaching approaches differ.

The Ministry of Education supports 16 trade schools through its Vocational Industrial Training Board (VITB). The trade schools offer 13 trade courses, giving the qualification of National Trade Certificate.

At the 'middle level' the Ministry of Education supports two polytechnics:

- the Singapore Polytechnic; and
- the Ngee Ann Polytechnic.

The polytechnics offer diploma courses which are mostly taken full-time but may be taken part-time. The Diploma courses are two years full-time with 'A' level entry or three years full-time with 'O' level entry (the secondary school system is similar to that of the United Kingdom).

Two institutions offer degree courses in Singapore:

- the National University of Singapore; and
- The Nanyang Technological Institute.

The Economic Development Board supports three institutions offering courses at the trade level:

- the Philips Government Training Centre;
- the Precision Engineering Institute (formerly the Brown Boverie Government Training Centre and the Tata Government Training Centre); and
- the Japan Singapore Technical Institute.

The trade training involves two years full-time at the institution with a further two years in industry. The qualification gained is a National Trade Certificate from the Ministry of Education's VITB plus a certificate from the Economic Development Board. The Precision Engineering Institute and the Japan Singapore Technical Institute also offer higher courses approximately equivalent to Australia's Advanced Trade Certificate.

At the 'middle level' the Economic Development Board supports:

- the German Singapore Institute; and
- the French Singapore Institute.

The German Singapore Institute has a focus on production engineering while the French Singapore Institute has a focus on Electronic Engineering. Both offer Diploma courses with a duration of two years full-time (with 'A' level entry) or three years full-time (with 'O' level entry).

Economic Development Board courses generally differ from Ministry of Education courses with respect to the emphasis on learning through practical work (EDB courses have higher practical emphasis).

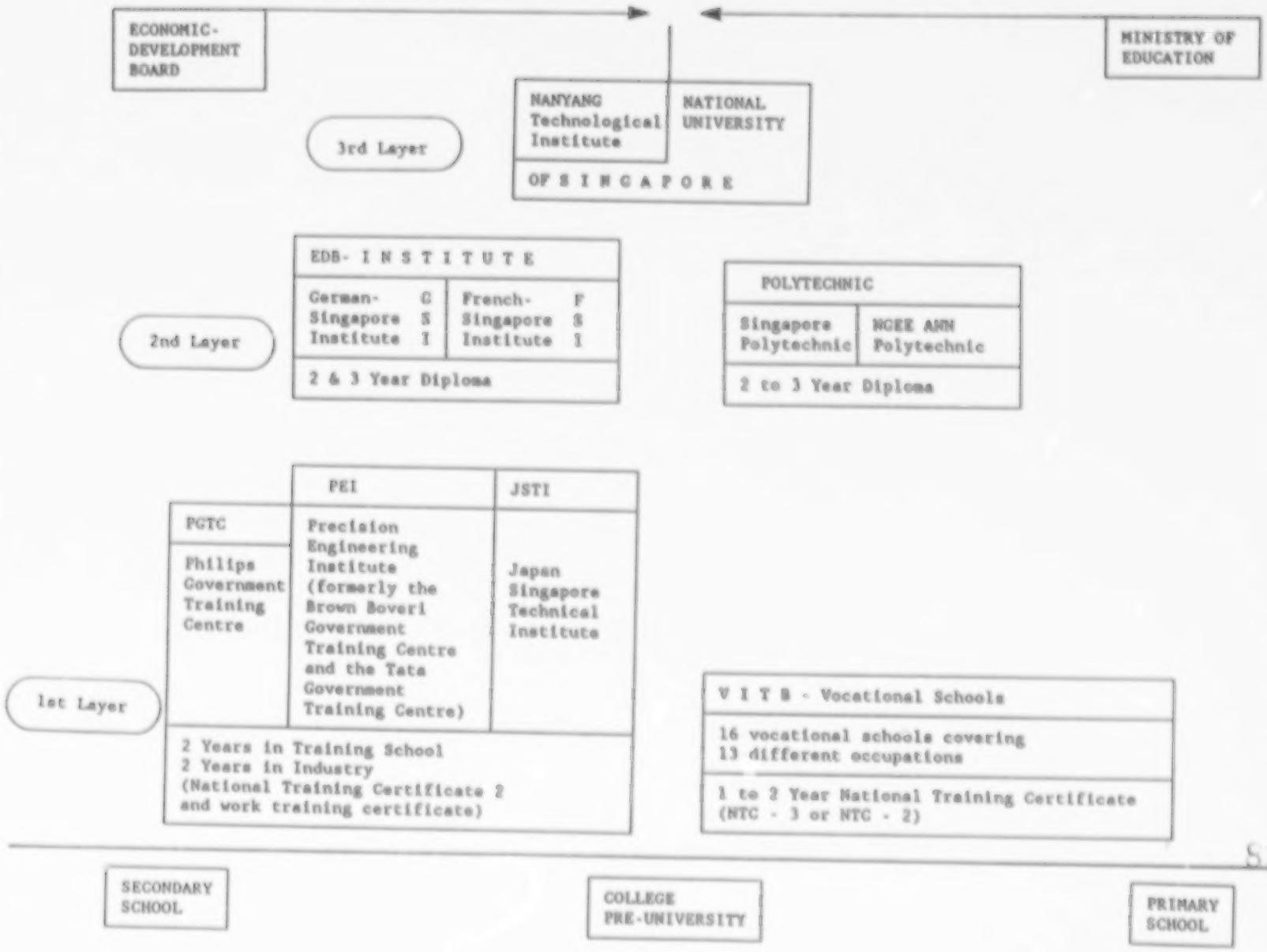


Figure 2: Singapore's tertiary education

FUNCTIONS OF THE GERMAN SINGAPORE INSTITUTE

GSO courses include:

- the diploma course in production engineering (2 or 3 years full-time), now with two specialist options in the final year:
  - production technology,
  - industrial automation;
- a one-year advanced course for students who have completed the production engineering diploma;
- ad-hoc short courses for industry; and
- train-the-trainer courses (not running in 1988).

In addition, GSI occasionally runs special workshops and seminars (e.g. when overseas experts are in Singapore) and hosts exhibitions of equipment.

LINKS WITH INDUSTRY

GSI has developed close links with Singapore industry by offering consultation in its areas of expertise. Mostly this is offered free of charge. GSI also undertakes specific projects at the request of industry. Most of these projects form part of the final year of the Diploma course. A team of students is assigned to each project, and the team is given three months to complete the project and report the outcomes. Larger projects likely to require more than three months to complete are undertaken by the Industrial Project Group (IPG). Such projects are undertaken by IPG technical staff within the GSI, students, and lecturing staff.

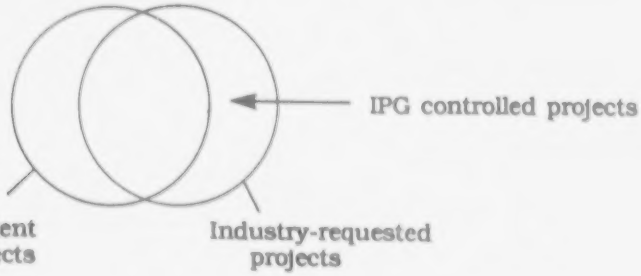
Each company requesting a project is asked to:

- pay for all hardware and material costs;
- appoint a co-ordinator within the company; and
- pay a small additional fee.

The relationship between the student projects and the industry-requested projects is shown in Figure 3.

Projects are of thee broad types:

- software development (e.g. for CNC, CAD/CAM, CAP);
- hardware development (e.g. robots, automated systems); and
- problem-solving (e.g. methods and plant layout involving extension 'on-site' work by students).



In addition to the Industrial Project Group, the Applied Technology Group (ATG) helps to develop links with industry. ATG has three full-time staff plus a number of part-time staff at the German Singapore Institute. As an initiative of the Economic Development Board, the ATG also operates from another EDB institution, the Precision Engineering Institute (PEI). The ATG aims to help local manufacturers adopt advanced manufacturing technologies. It does this by procuring equipment and expertise from leading international manufacturers and offering 'upgrading programs' for engineers and technicians in the local industry. The equipment and expertise is located at the German Singapore Institute and the Precision Engineering Institute. Their combined facilities offer over:

- 160 CAD/CAM/CAE work stations;
- 30 industrial robots; and
- 30 CNC machines.

Thus the hardware, software and interaction with industry enhance the training within the two Institutions' mainstream courses.

THE PRODUCTION ENGINEERING DIPLOMA

The Production Engineering Diploma is the main course offered by the German Singapore Institute.

An outline of the structure of the Production Engineering Diploma course is shown in Figure 4. This shows the new course structure with two main electives:

- production technology (including tool design and CNC technology);
- industrial automation (including control, electronics, systems design and peripherals).

In addition to these two electives, a separate plastics technology elective is being developed to be offered in the future.

Formerly the Production Engineering Diploma had the following three electives:

- cutting technology and CNC techniques;
- design (tool and die/jigs and fixtures): and
- industrial automation.

At the time of writing, both the new and old course structures are in operation.

The subjects within each box shown in Figure 4 are listed in Table 1. Notable features include:

- the emphasis on project work (in teams) in the final year;
- the greater emphasis on practical work for 'A' level students;
- the teaching of the German language; and
- the teaching of 'work pedagogics'.

FIGURE 4: STRUCTURE OF THE PRODUCTION ENGINEERING DIPLOMA

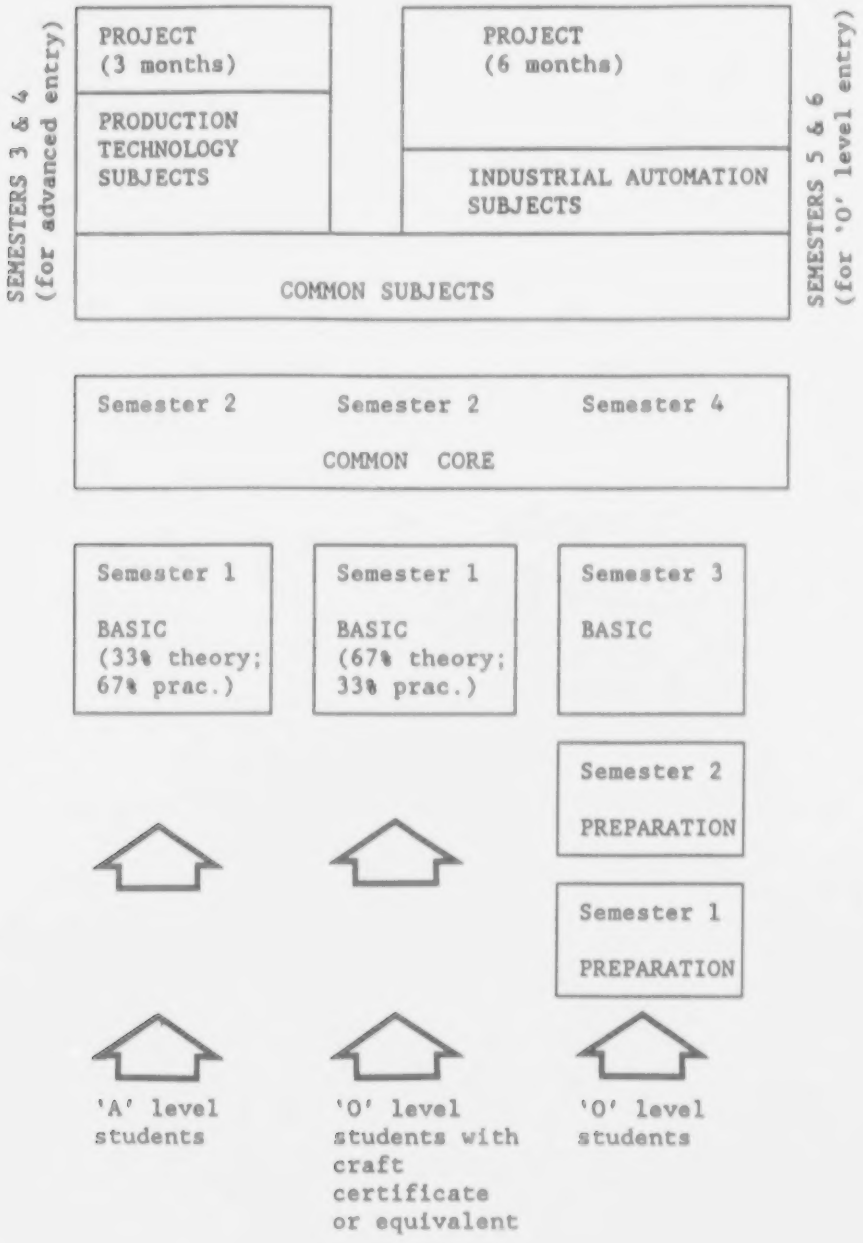


Figure 4: **Structure of the Production Engineering Diploma**

	SUBJECTS	Tools and Comp Mfg (TCM) Group	Industrial Automation (IA Group)
YEAR 2	1. Workshop Practice III	100 (TU)	- (TU)
	2. Quality Control III	60	-
	3. Design II (Jigs & Fixtures)	180	-
	4. Plastics Technology II	90	-
	5. CNC Technology	100	-
	6. Optional subject (*)	508	-
	a) Adv. CNC Technology		
	b) Tool Design		
	7. Mini Project related to 6(a) & 6(b)	246	-
	1. Industrial Automation III (Control & Electronics)	-	322
	2. Industrial Automation IV (Systems Peripherals)	-	368
	SUB TOTAL	1284 TU	690 TU
	Surface Treatment	46	46
	Industrial Automation II (including Robotics)	92	92
	Production Management & Control	138	138
	Quality Control II	69	69
	German Language	92	92
	Work Pedagogics	46	46
	Tutorial & Self-study	69	69
	Semestral Exam	108 TU	54 TU
	SUB TOTAL	660 TU	606 TU
	TOTAL TRAINING HOURS (excluding Project Work)	1944 TU	1296 TU
	PROJECT WORK	(3 months)	(6 months)

YEAR 1 (24 WKS=1296 TU)	COMMON CORE	1. Production Techniques II -	1.1 Cutting Tech & Metal Forming) 1.2 CNC Technology A) 207 1.3 Welding Technology)
		2. Workshop Practices II -	2.1 Cutting Tech & CNC Machining) 138 2.2 Tool & Die Making)
		3. Mechanics II	69
		4. Materials Technology II -	4.1 Heat Treatment 69 4.2 Materials Testing 69
		5. Plastics Technology I	69
		6. Design I	138
		7. Industrial Automation I	92
		8. Industrial Management I	92
		9. EDP I	46
		10. Quality Control I (Metrology)	69
		11. German Language II	92
		12. Tutorial, Self-study & Exam.	146

	A - LEVEL STUDENTS		CRAFTSMAN STUDENTS	
BASIC COURSE (24 WKS=1296 TU)	A. WORKSHOP PRACTICE	828	A. WORKSHOP PRACTICE	322
	1. Bench Work, Fitting & Shaping		B. THEORY	
	2. Turning		1. Mechanics I	92
	3. Milling		2. Production Tech I	92
	4. Grinding		3. Materials Tech I	
	5. Welding, Brazing, Forging		3.1 Materials Science A	46
	B. THEORY		3.2 Chemistry	46
	1. Mechanics I	92	4. Engineering Drawing	46
	2. Production Tech I	92	5. German Language I	92
	3. Materials Tech I		6. Engineering Science	92
	3.1 Materials Science A	46	6.1 Physics	92
	4. Engineering Drawing	92	6.2 Electro-techniques	92
	5. German Language	92	7. Engineering Maths	184
	6. Tutorial, Self-study & Exam	54	8. Tutorial, Self-study & Exam	192

Table 1: The Production Engineering Diploma course subjects (2 year course)

EQUIPMENT

The German Singapore Institute has a layout similar to a modern manufacturing company, with production areas and technical laboratories. There are very few theory classrooms. The workshops and laboratories include:

- Department for production planning & control
- Various production workshops for metal machining and Plastic Technology
- Department for Design & Development
- Laboratories for quality control & material testing
- Workshops for tool & die fabrication and heat treatment
- Laboratories for material management, material handling, automated assembly and robotics.

In the CADCAM/CAE area, a range of hardware and software is available, and this includes:

- 15 Computervision INSTAVIEW Stations on CDS4000/Designer VX Systems
- 34 HP 9000 series, model 220, 310 and 320 Work stations with networking
- IBM PC AT, Philips P3200, NEC APC IV and COMPAQ 386 PCs
- Computervision software, including:
  - CADDS 4 X
  - PERSONAL DESIGNER
  - PERSONAL
  - MACHINISTS etc.
- Hewlett Packard software, including:
  - ME 10, EGS, HP NC, AC
  - CIRCUIT ANALYSIS
  - WAVEFORM ANALYSIS
- Autodesk software - AUTOCAD.

TEACHING APPROACH

There is a marked emphasis on practical work in the courses offered by GSI.

In the Production Engineering Diploma, theory classes only predominate in the early part of the course for students entering with 'O' level passes from school. Thereafter, practical classes are chiefly conducted in a factory production environment is the main teaching approach. Students entering from school with 'A' level passes start with a heavy emphasis on practical work (see Figure 4).

In the final semester of the Production Engineering Diploma, 3 - or 6 - month projects are undertaken by the students. During the full-time project phase, students are usually organised in groups to encourage teamwork.

These projects, many of which are sponsored by local industries, are instrumental in assessing the students' ability to apply and integrate the knowledge that they have acquired throughout the course and also for enabling them to gain relevant industrial experience.

For most of the projects, the students are involved in the following activities:

- planning;
- designing;
- sourcing/procuring of materials;
- fabricating and assembling; and
- troubleshooting and commissioning.

To simulate industrial requirements, projects are carried out under budget and time constraints. Microcomputer-based project management software is used to help students to plan and monitor the progress of their projects.

The assessment criteria are based on the continual monitoring of the students' progress, project presentation, project documentation and hardware, where applicable.

EXAMPLES OF INTEGRATED MANUFACTURING COURSES

The following course summaries are for programs specifically related to the principles and techniques of Integrated Manufacturing. The examples are from a South Australian TAFE College, Ngee Ann Polytechnic (Singapore), the German-Singapore Institute, and Oakland Community College (Detroit, USA).

Example 1: Regency College of TAFE, South Australia

School of Mechanical Engineering - Associate Diploma in Mechatronic Engineering

Semester 1 (18) weeks

a)	Principles of Fabrication	4 hours/week
b)	Computing	2 hours/week
c)	Introductory Electricity	3 hours/week
d)	Electronic Principles	3 hours/week
e)	Engineering Mechanics	3 hours/week
f)	Applied Mathematics	4 hours/week
g)	Engineering Orientation	2 hours/week

Semester 2 (18 weeks)

a)	Principles of Fabrication (ctd)	4 hours/week
b)	Introductory Electricity (ctd)	3 hours/week
c)	Electronic Principles (ctd)	3 hours/week
d)	Engineering Mechanics (cdt)	3 hours/week
e)	Computing (ctd)	4 hours/week
f)	Engineering Measurement (cdt)	3 hours/week

Semester 3 (18 weeks)

a)	Engineering Systems A	4 hours/week
b)	Engineering Systems B	4 hours/week
c)	Control Principles 1	2 hours/week
d)	Control Principles 2	3 hours/week
e)	Engineering Measurement (ctd)	3 hours/week
f)	Computer Systems	3 hours/week
g)	Materials	3 hours/week

Semester 4 (18 weeks)

a)	Engineering Systems A (ctd)	4 hours/week
b)	Engineering Systems B (ctd)	4 hours/week
c)	Principles of Management	3 hours/week
d)	Control Principles 1 (ctd)	2 hours/week
e)	Control Principles 2 (ctd)	3 hours/week
f)	Computer Systems (ctd)	3 hours/week
g)	Design Project	3 hours/week

Example 2: Regency College of TAFE, South Australia

School of Mechanical Engineering - Associate Diploma in Computer Integrated Manufacture

This Associate Diploma Course is also offered at Regency College (and specific units in other colleges), and is of 1536 hours duration taken over two years full-time study.

Common Core (596 hours)

a) Engineering Mathematics 1	108 hours
b) Engineering Mechanics 1	108 hours
c) Engineering Drawing and Design 1	108 hours
d) Workshop Practice	88 hours
e) Introduction to Computing	40 hours
f) Communication	72 hours
g) Engineering Materials	72 hours

Essential Studies (576 hours)

a) Numerical Control Programming and Practice 1	54 hours
b) Numerical Control Programming and Practice 2	54 hours
c) Computer Programming	36 hours
d CIMM Systems	108 hours
e) Computer Aided Manufacturing Systems	54 hours
f) Manufacturing Technology	108 hours
g) Physics of Engineering Measurement	108 hours
h) CAD Systems	54 hours

Electives (220 hours minimum)

a) Producing Planning and Control	108 hours
b) Numerical Control Tooling and Machining	36 hours
c) Introduction to Automatically Programmed Tools (APT)	36 hours
d) Alternate Numerical Control Computer Language	36 hours
e) Quality Control	108 hours
f) Robotics 1	36 hours
g) Maintenance Management	72 hours
h) Plastic Materials	72 hours
i) Technology of Plastics Processes 1	108 hours
j) Technology of Plastics Processes 2	108 hours
k) Engineering Management	108 hours
l) Computer Aided Design 1	72 hours
m) Computer Aided Design 2	80 hours
n) Industrial Control Systems	108 hours
p) Production Organisation	108 hours

Engineering Project (144 hours)

Example 3: Ngee Ann Polytechnic, Singapore

Diploma in Mechanical Engineering

The Diploma in Mechanical Engineering is a 2 or 3 year full-time course (depending on entry status).

'A' Level (2 year course)

Year 1	Hours/Week Lecture/ Tutorial	Lab/ Practical
Computer Programming	1.1/2	1
Electrotechnology	3	1
Engineering Materials	3	1
Workshop Technology and Machine Tool Maintenance	3	4
Applied Mechanics	3	1
Engineering Drawing, Design and Computer Aided Drafting	1	4
Thermofluid Technology and Pollution Control	3	1
Industrial Automation 1	3	1

Final Year

Common Subjects

Mechanics of Materials and Machines	2	1
Supervisory Management	3	1
Project	1	4
Computer Applications	0	1

Elective Option 1:
Plant Design and Maintenance Technology

Process Instrumentation and Control	2	1
Engineering System Design	1	3
Thermofluid Technology III	2	2
Plant Maintenance Engineering A	2	2
Plant Maintenance Engineering B	2	2

Elective Option 2:
Refrigeration and Air Conditioning Technology

Process Instrumentation and Control	2	1
Thermofluid Technology III	2	2
Industrial Refrigeration	2	2
Energy System Management	2	1
Air-Conditioning and Computer Aided Design	2	3

Elective Option 3:
Fabrication Technology

Welding Technology and Non-Destructive Testing (NDT)	2	2
Metal Forming and Casting Technology	2	2
Heat Treatment Technology	2	2
Industrial Automation II	2	2
CNC Technology	2	2

Elective Option 4:
Manufacturing Technology

Industrial Automation II	2	2
CNC Technology	2	2
Manufacturing Processes	2	2
Tool, Die and Mould Design	2	2
Metrology and Quality Control	2	1

Elective Option 5:
Industrial Automation Technology

CNC Technology	2	2
Industrial Automation and Digital Control Systems	2	2
Process Instrumentation and Servo Control	2	1
Robotics	2	2
Factory Automation Systems	1	3

Example 4: German-Singapore Institute, Singapore

Diploma in Production Engineering

The Diploma is offered as a two year full-time course with two streams, with entry depending on student's grades.

	SUBJECTS	Tools and Comp Mfg (TCM) Group)	Industrial Automation (IA Group)
YEAR 2	1. Workshop Practice III	100 (TU)	- (TU)
	2. Quality Control III	60	-
	3. Design II (Jigs & Fixtures)	180	-
	4. Plastics Technology II	90	-
	5. CNC Technology	100	-
	6. Optional subject (*)	508	-
	a) Adv. CNC Technology		
	b) Tool Design		
	7. Mini Project related to 6(a) & 6(b)	246	-
	1. Industrial Automation III (Control & Electronics)	-	322
	2. Industrial Automation IV (Systems Peripherals)	-	368
	SUB TOTAL	1284 TU	690 TU
	Surface Treatment	46	46
	Industrial Automation II (including Robotics)	92	92
	Production Management & Control	138	138
	Quality Control II	69	69
	German Language	92	92
	Work Pedagogics	46	46
	Tutorial & Self-study	69	69
	Semestral Exam	108 TU	54 TU
	SUB TOTAL	660 TU	606 TU
	TOTAL TRAINING HOURS (excluding Project Work)	1944 TU	1296 TU
	PROJECT WORK	(3 months)	(6 months)

YEAR 1	COMMON CORE (24 WKS= 1296 TU)	1. Production Techniques II	1.1 Cutting Tech & Metal Forming) 1.2 CNC Technology A) 1.3 Welding Technology)	207
		2. Workshop Practices II	2.1 Cutting Tech & CNC Machining) 2.2 Tool & Die Making)	138
		3. Mechanics II		69
		4. Materials Technology II	4.1 Heat Treatment 4.2 Materials Testing	69 69
		5. Plastics Technology I		69
		6. Design I		138
		7. Industrial Automation I		92
		8. Industrial Management I		92
		9. EDP I		46
		10. Quality Control I (Metrology)		69
		11. German Language II		92
		12. Tutorial, Self-study & Exam.		146
	BASIC COURSE (24 WKS= 1296 TU)	A. WORKSHOP PRACTICE	828	A. WORKSHOP PRACTICE 322
		1. Bench Work, Fitting & Shaping		B. THEORY
		2. Turning		1. Mechanics I 92
		3. Milling		2. Production Tech I 92
		4. Grinding		3. Materials Tech I
		5. Welding, Brazing, Forging		3.1 Materials Science A 46
		B. THEORY		3.2 Chemistry 46
		1. Mechanics I	92	4. Engineering Drawing 46
		2. Production Tech I	92	5. German Language I 92
		3. Materials Tech I		6. Engineering Science 92
		3.1 Materials Science A	46	6.1 Physics 92
		4. Engineering Drawing	92	6.2 Electro-techniques 92
		5. German Language	92	7. Engineering Maths 184
		6. Tutorial, Self-study & Exam	54	8. Tutorial, Self-study & Exam 192
		A - LEVEL STUDENTS		CRAFTSMAN STUDENTS

Example 5: Oakland Community College, Auburn Hills Campus, Detroit (USA).

An Associate Degree is offered as a 2 1/2 year full-time course, or part-time. The course comprises four types (or levels) of subjects, as follows:

Level I Major Course work

CIM 110 Introduction to Computer Integrated Manufacturing
CIM 130 Manufacturing Resource Planning (MRP 11)
CIM 210 Plant Operation Networking
CIM 220 Machine Tool Communications
CIM 230 Introduction to Flexible Manufacturing Systems (FMS)
CIM 240 FMS Applications
CIM 250 Simulation of Plant Operations

Level II Direct Support Courses

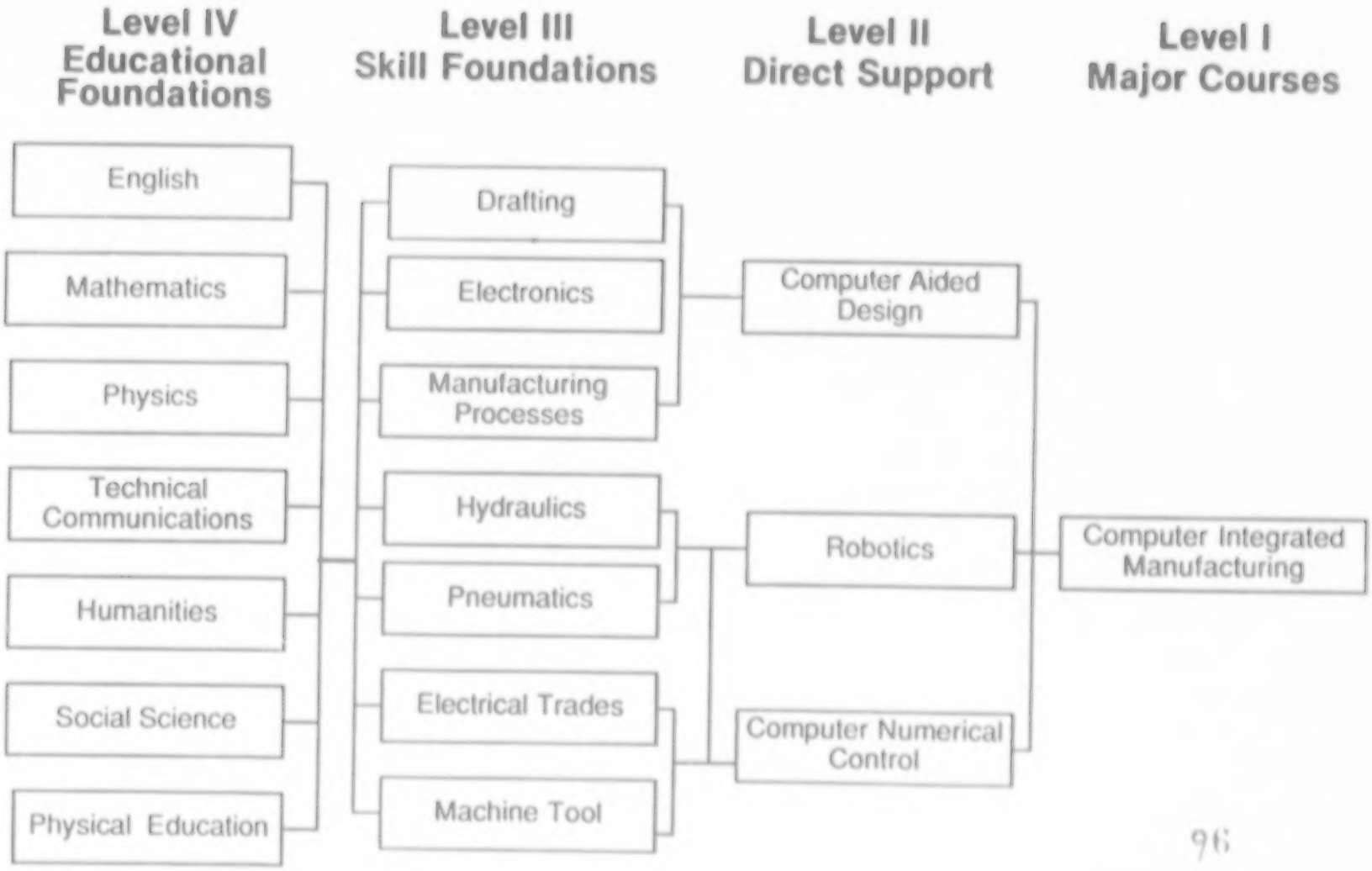
ROB 150 Introduction to Robotics
ROB 204 Electrical Automation Circuits and Logic Fundamentals
CAD 110 Introduction to Computer Aided Design
CAD 120 Computer Aided Design Applications I
CAD 130 Computer Aided Design Applications II
ATM 130 Introduction to Numerical Control
ATM 210 Basic Numerical Control Programming
ATM 220 Numerical Control Machining

Level III Skill Foundation Courses

ECT 208 Introduction to Microprocessors
ATM 110 Introduction to Machine Tools
ATM 112 Machine Tool Operation
MEC 101 Introduction to Manufacturing Processes
ETT 101 Electrical Fundamentals I (D.C.)
ETT 103 Electrical Fundamentals II (A.C.)
ETT 131 Introduction to Electronics
DRT 111 Introduction to Technical Drawing
DRT 112 Technical Drawing Applications
DRT 116 Applied Descriptive Geometry

Level IV Educational Foundations

APM 811 Geometry-Algebra
MAT 115 Intermediate Algebra
ENG 134 Technical Communications
ENG 211 Technical Writing
SPE 129 Interpersonal Communications
PHY 161 College Physics

The following diagram illustrates the relationship between the four levels in the CIM associate degree.

COMPUTER INTEGRATED MANUFACTURING
CURRICULUM DIAGRAM